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EFFECTS OF TIME-SHIFTED DATA ON FLIGHT-DETERMINED STABILITY AND CONTROL DERIVATIVES

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16. Abstract

Flight data from five aircraft were shifted in time by various increments to assess the effects of time shifts on estimates of stability and control derivatives produced by a maximum likelihood estimation method.

Derivatives could be extracted from flight data with the maximum likelihood estimation method even if there was a considerable time shift in the data. Time shifts degraded the estimates of the derivatives, but the degradation was in a consistent rather than a random pattern. Time shifts in the control variables caused the most degradation, and the lateral-directional rotary derivatives were affected the most by time shifts in any variable.

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INTRODUCTION

The effects of data processing and instrumentation errors on flight-determined stability and control derivatives is an important yet seldom treated subject in aircraft parameter estimation technology. It is desirable to minimize the errors, noise, and uncertainties in any data acquisition system used in flight testing, but this is sometimes impossible because of such program constraints as tight scheduling, lack of funds, or the unavailability of the necessary equipment. In addition, one set of instrumentation must often be used for several flight test objectives, so it cannot be optimized for the determination of stability and control derivatives.

Some studies of the effects of instrumentation errors on the accuracy of derivatives determined from flight test data have been made (refs. 1 and 2); however, these studies did not treat the question of time-shifted data. Time shifts can and often do occur in flight test data. One type of time shift occurs because of the character of the data sampling systems. Although it is usually assumed that all the signals recorded in a pulse code modulation (PCM) system are sampled simultaneously, there is a significant amount of time between the sampling of each signal. If, in addition, some of the signals are sampled at the extremes of the sample interval, a time shift, although less than the sample interval, occurs. This type of shift is particularly pronounced in systems with low sampling rates. Another common cause of time shifting is signal filtering. A properly designed filter results in a smoother signal at the expense of producing some time delay.

It is also possible to encounter an effective time lead in one of the signals in a modern data acquisition system. A time lead can occur if all except one of the signals is filtered. The unfiltered signal then leads the other signals. In addition, if one signal is sampled at the end of a time interval and the rest are sampled at the beginning, the first signal appears to lead the others. Therefore, the effects of time leads as well as those of time lags should be examined.

Advanced parameter estimation techniques (such as that in ref. 3), which are coming into widespread use, involve matching a computed time history with a flight-measured time history for the same control input. There has been some concern as to how well this approach would work if significant phase or time shifts were present in the flight data.

This report presents the results of determining stability and control derivatives with a maximum likelihood estimation method from flight data that have been time shifted. Data acquired from five aircraft and from both lateral-directional and longitudinal maneuvers are considered.

SYMBOLS

The data in this report are referred to the body system of axes. Physical quantities are presented in the International System of Units (SI) and parenthetically in U.S. Customary Units. Measurements were taken in U.S. Customary Units.

a_n normal acceleration, g

a_y lateral acceleration, g

L_p partial dimensional derivative of roll acceleration with respect to roll rate, rad/sec

L_r partial dimensional derivative of roll acceleration with respect to yaw rate, rad/sec

L_β partial dimensional derivative of roll acceleration with respect to angle of sideslip, rad/sec^2

L_{δ_a} partial dimensional derivative of roll acceleration with respect to aileron deflection, rad/sec^2

L_{δ_r} partial dimensional derivative of roll acceleration with respect to rudder deflection, rad/sec^2

M_q partial dimensional derivative of pitch acceleration with respect to pitch rate, rad/sec

M_α partial dimensional derivative of pitch acceleration with respect to angle of attack, rad/sec^2

M_{δ_e} partial dimensional derivative of pitch acceleration with respect to elevator deflection, rad/sec^2

N_p partial dimensional derivative of yaw acceleration with respect to roll rate, rad/sec

N_r partial dimensional derivative of yaw acceleration with respect to yaw rate, rad/sec

N_α partial dimensional derivative of normal force divided by mass times velocity with respect to angle of attack, rad/sec

N_β partial dimensional derivative of yaw acceleration with respect to angle of sideslip, rad/sec^2

N_{δ_a} partial dimensional derivative of yaw acceleration with respect to aileron deflection, rad/sec^2

N_{δ_e} partial dimensional derivative of normal force divided by mass times velocity with respect to elevator deflection, rad/sec

N_{δ_r} partial dimensional derivative of yaw acceleration with respect to rudder deflection, rad/sec^2

p roll rate, deg/sec

$\dot{p}$ rolling angular acceleration, deg/sec^2

$\bar{q}$ dynamic pressure, kN/m^2 (lb/ft^2)

q pitch rate, deg/sec

r yaw rate, deg/sec

$\dot{r}$ yawing angular acceleration, deg/sec^2

V velocity, m/sec (ft/sec)

Y_β partial dimensional derivative of side force divided by mass times velocity with respect to angle of sideslip, rad/sec

α angle of attack, deg

β angle of sideslip, deg

δ_a left aileron deflection minus right aileron deflection, deg

δ_e elevator deflection, deg

δ_r rudder deflection, deg

δ_1 reaction control, percent

θ pitch angle, deg

φ bank angle, deg

AIRCRAFT AND FLIGHT TEST CONDITIONS

Flight test data from several types of aircraft were analyzed to obtain results that were independent of aircraft configuration. The choice of aircraft was based largely on the availability of the proper dynamic response data for determining stability and control derivatives. The data are from current or recently completed flight test programs at the NASA Flight Research Center.

Data from five aircraft, referred to as aircraft A, B, C, D, and E, were used. Aircraft A was an F-8C fighter with a supercritical wing and is described in reference 4. An F-111A fighter with a variable sweep wing (ref. 5) was aircraft B. The Lockheed JetStar airplane, a low-winged, executive jet transport, was aircraft C (ref. 6). Aircraft D was a conventional F-8C configuration, which has a high, variable incidence wing (ref. 7). The M2-F3 lifting body research vehicle was aircraft E (ref. 8).

Table 1 lists the conditions under which the data for the five aircraft were acquired. All the tests were performed at a nominal load factor of 1g with stability augmentation systems off.

DATA ACQUISITION

All the test aircraft used in the study were instrumented to measure three-axis linear acceleration and angular rates, Euler angles, angle of sideslip, angle of attack, control surface deflections, velocity, and altitude. The data were recorded on a PCM magnetic tape system. The basic sampling rates were 50 samples per second for aircraft A, 20 samples per second for aircraft B, and 200 samples per second for aircraft C, D, and E. The data were processed at various sample rates (table 1).

Before being encoded and recorded by the PCM system, the data were filtered with a passive first-order filter. All known phase shifts due to the instrumentation filters were accounted for.

METHOD OF ANALYSIS

The first step in the method used to assess the effect of time shifting was to obtain baseline values of the derivatives by using a maximum likelihood estimation program and a good set of flight data for each aircraft. Time shifts were then applied to the recorded signal of one response or control variable and a new set of derivatives was obtained. The difference in the derivatives was attributed to the time shift in the signal shifted.

The flight data for each aircraft used in this analysis and the corresponding computed time histories resulting from use of the maximum likelihood estimation method are presented in figures 1 and 2 for the lateral-directional and longitudinal maneuvers, respectively. The type of input for each maneuver is listed in table 1. The baseline values of the derivatives are presented in table 2.

Maximum Likelihood Estimation Method

The dimensional stability and control derivatives were determined by using the maximum likelihood estimation method described in reference 3. This method is a digital computational technique that determines the best set of coefficients (stability and control derivatives) of the linearized equations of motion in such a way that a weighted integral squared error between flight-measured and computed time histories is minimized. The result is that the computed time history tends to match the flight time history. The signals used in the error minimization for each vehicle are shown in figures 1 and 2. The elements of the weighting matrices for each vehicle (discussed in general in ref. 3) are given in table 3.

By using the Cramèr-Rao bound, the maximum likelihood estimation method also provides an estimate of the degree of confidence that should be placed in the derivatives extracted from flight data. This bound provides an estimate of the lower bound of the covariance of the parameters estimated from a given set of flight data. Reference 3 discusses the Cramèr-Rao bound more fully.

Data Time-Shifting Procedure

Time shifts were made in the positive time direction, corresponding to a time delay or phase lag in that variable, and the negative time direction, corresponding to a time advance or phase lead in that variable. The time-shifted sets of data were then processed with the maximum likelihood estimation program to obtain new estimates of the derivatives for comparison with the baseline values.

The flight response and control variables that were time shifted for the lateral-directional maneuvers were p, β, and either δ_a or δ_r, or both, depending on the type of control input involved. Although δ_r was an input to aircraft D, it was not shifted nor were the values of the rudder derivatives included. For the longitudinal maneuvers, the time-shifted variables were α, q, and δ_e. Each variable was shifted from 1 to 10 time increments, or until the maximum likelihood estimation computer algorithm no longer converged to an answer. The maximum time shift for the various aircraft varied because the sample rates for the aircraft differed.

RESULTS AND DISCUSSION

Effect of Time Shifts on Time History Matches

As expected, the matches between flight and computed time histories that resulted when time-shifted data were used were poor compared with the matches obtained with nonshifted data. Figures 3(a) and 3(b) show the matches that resulted with time shifts in β of -0.32 second and +0.32 second, respectively, for the lateral-directional time history from aircraft A. These matches should be compared with the match in figure 1(a), which was obtained with nonshifted data. The comparison shows that a time shift in one variable, β in this case, affected the match of all the other response variables. In some flight data, a time shift in β of this magnitude degraded the match so much that the maximum likelihood estimation algorithm diverged and no results could be obtained. It was also observed that the number of iterations required for convergence increased with increasing time shift. Divergence occurred most often when control variables were shifted significantly, especially if the control variable lagged the other signals so that the aircraft appeared to respond before the control input was made. However, in most cases the maximum likelihood estimation program converged to a reasonable, although significantly different, answer even if time delays or advances were substantial.

Effect of Time Shifting on Derivative Estimates

The stability and control derivatives determined for each set of time-shifted data are presented as functions of the time-shift increments for the five lateral-directional maneuvers in figures 4 to 8 and for the two longitudinal maneuvers in figures 9 and 10. The trends that resulted from the time shifts are shown in figure 11. Table 4 lists the derivative estimates plotted in figures 4 to 10.

The percentages of change in the derivatives for a 0.1-second time shift are summarized for the lateral-directional maneuvers in table 5 and for the longitudinal maneuvers in table 6. Changes for a 0.1-second time shift were compared because a time shift of this magnitude is representative of the shifts that exist in poorly specified data acquisition systems. Where data were not calculated for a time shift of exactly 0.1 second, values of the derivatives were interpolated.

Estimates of the derivatives could be obtained by using the maximum likelihood estimation method even when the time shifts in the data were considerable. In addition, when the time-shifted data were plotted as a function of the time-shift increment, well defined trends in the derivatives resulted instead of randomly occurring derivative values. However, the response of the different derivatives to a time shift in one signal varied greatly, and the response of each derivative varied according to the signal being shifted. Some generalizations can be made, because some effects are independent of the type of aircraft or maneuver, although with a sample as small as this one the results cannot be taken as conclusive for all aircraft. It may be concluded that time shifts had a significant effect on the estimates of the derivatives. Therefore, if filters that produce significant time lags must be used, the same filter should be applied to all signals to eliminate different time shifts for different recorded signals.

<u>Lateral-directional derivatives</u>.— The percentage of change in each derivative was computed for a 0.1-second time shift in each signal, using the value of the unshifted derivative as the baseline value. Some of the percentages of change are large because the baseline values are close to zero. The lateral-directional results, which are summarized in table 5 and figure 11(a), indicate that in general the

static derivatives, N_β, L_β, and Y_β, change only a little with shifts in any signal for any aircraft. The principal exceptions are the larger error in L_β for aircraft A and D and N_β for aircraft D. The percentage of change in L_{δ_a} was small for most shifted signals, and the direction of the change was the same for all the aircraft. For L_p, the direction of the changes was consistent among the aircraft, but the large percentage of change indicates that for some aircraft the estimate of this derivative is degraded significantly by even a slight time shift in any of the signals chosen. Significant but less consistent changes are apparent in N_{δ_a} and L_{δ_r} and the rotary derivatives, N_r, L_r, and N_p. For the most part, the effect of time shifting β was less than that of time shifting the other signals, although a large enough shift in β resulted in the divergence of the algorithm.

Table 7, which is readily obtained from table 5, shows how greatly a time shift of 0.1 second in each signal affected the lateral-directional derivatives. The significant changes, based only on the data analyzed, may also be summarized as follows:

The 0.1-second time shift in roll rate, p, resulted in 10-percent to 25-percent changes in the estimation of L_β, L_{δ_r}, N_{δ_a}, and L_{δ_a} and in greater than 25-percent changes in the estimation of N_r, L_r, N_p, and L_p.

The 0.1-second time shift in sideslip, β, resulted in 10-percent to 25-percent changes in the estimation of N_r, L_r, L_{δ_r}, and N_{δ_a} and in greater than 25-percent changes in the estimation of N_p.

The 0.1-second time shift in aileron control, δ_a, resulted in 10-percent to 25-percent changes in the estimation of L_β, N_{δ_r}, N_{δ_a}, and L_{δ_a} and in greater than 25-percent changes in the estimation of N_r, L_r, N_p, L_p, and L_{δ_r}.

The 0.1-second time shift in rudder control, δ_r, resulted in 10-percent to 25-percent changes in the estimation of N_β and in greater than 25-percent changes in the estimation of N_r, L_r, N_p, L_{δ_r}, and N_{δ_a}.

Longitudinal derivatives.— The effects of a 0.1-second time shift on the longitudinal derivatives are summarized in table 6 and figure 11(b). The percentage of change in M_α is consistently small and the direction of change is the same for both aircraft. Less significant changes are apparent in N_α, M_q, N_{δ_e}, and M_{δ_e} (table 6).

For the most part, the effects of shifting α and q were smaller than the effects of time shifting δ_e.

The longitudinal derivatives extracted in this analysis are listed in table 8 along with an indication of how greatly each was affected by the 0.1-second time shifts. The table is based on table 6. The significant changes in the stability and control derivatives from table 8, based only on the data analyzed, are summarized below.

A 0.1-second time shift in angle of attack, α, resulted in 10-percent to 25-percent changes in the estimation of M_q and in greater than 25-percent changes in N_{δ_e}.

A 0.1-second time shift in pitch rate, q, resulted in changes of greater than 25 percent in the estimation of N_{δ_e}.

A 0.1-second time shift in elevator control, δ_e, resulted in changes of 10 percent to 25 percent in the estimation of M_α and M_{δ_e} and in changes of greater than 25 percent in the estimation of M_q and N_{δ_e}.

It can be concluded from the data for the lateral-directional and longitudinal derivatives that if it is desirable to obtain accurate estimates of the less significant control derivatives (L_{δ_r}, N_{δ_a}, and N_{δ_e}) and the rotary derivatives (N_r, L_r, N_p, L_p, and M_q), time shifts in the response and control variables must be accounted for. The derivatives that have the greatest effect on the aircraft response, like N_β and M_α, were affected only by the larger control time shifts.

Consideration of Aircraft Characteristic Times

Another way to compare the effects on the derivatives of time shifting is to select a time shift that corresponds to a certain percentage of the aircraft's dominant characteristic time, since the effects of time shifts might be expected to be a function of the characteristic times. The percentages of change in the lateral-directional and longitudinal derivatives that resulted from a time shift equal to approximately 5 percent of the dominant characteristic time of each aircraft are listed in tables 9 and 10, respectively. The characteristic time is the period of the short period mode for the longitudinal derivatives or the Dutch roll mode for the lateral-directional derivatives. The characteristic time of each aircraft is given in table 1.

The results of this type of change, expressed as percentages, are approximately the same for each derivative as the results of a time shift of 0.1 second. Therefore, the effects of time shifting are not necessarily a strong function of the characteristic time of the aircraft.

Uncertainty Levels

To represent the validity of one derivative estimate in relation to another, uncertainty levels can be determined. Uncertainty levels can be calculated at the same time as the derivatives by using Cramèr-Rao bounds in the maximum likelihood estimation program. Theoretically, the smaller the uncertainty level, the more reliable the estimate of the derivative.

The vertical lines through the data points in figures 12 to 14 indicate uncertainty levels. (For this study, uncertainty levels are used in a relative sense only and are equal to 10 times the Cramèr-Rao bound, an approximation based on experience.) For the lateral-directional maneuvers, the lines through the center of the point correspond to the uncertainty level for a shift in p, those to the left of the point correspond to a shift in β, and those to the right correspond to a shift in δ_a and then δ_r. For the longitudinal maneuvers, the lines through the center of the points correspond to the uncertainty levels for a shift in α, those to the left correspond to a shift in q, and those to the right correspond to a shift in δ_e. The uncertainty levels for the maneuvers in figures 12, 13, and 14 are listed in tables 11(a), 11(b), and 11(c), respectively.

The trends of the uncertainty levels in figures 12 to 14 are consistent with the theoretical definition of uncertainty level. The uncertainty levels are the smallest for a zero time shift, and as the error (due to time shifting) increases, the size of the uncertainty level increases. Correspondingly, if the derivative is not changed significantly by the time shift, the uncertainty level remains small. The increase in uncertainty level with the decrease in the accuracy of the data provides added confidence in the results of the study.

For the longitudinal maneuvers, the uncertainty levels for each point include or nearly include the value of the zero time-shift point. For the lateral-directional data the uncertainty levels may occasionally have to be several times as great as those plotted to include the zero time-shift point.

CONCLUSIONS

The effects of time shifts in the flight measurements of the signals used to estimate stability and control derivatives were determined by time shifting one signal at a time in the positive and in the negative time direction. The derivatives for the data were extracted by using the maximum likelihood estimation method and analyzed as a function of the time-shift increment. Generalizations about the values of the data *per se* should not be made because the data base was small, but the following conclusions about the effects of time shifts on the data of this study may be drawn:

(1) Even with a significant time shift in the data, it was possible to obtain stability and control derivatives by using the maximum likelihood estimation method.

(2) The effect of time shifts on the derivatives produced results that were in consistent rather than random patterns.

(3) Time shifts degraded the accuracy of the derivative estimation. Shifting the control variables caused the greatest degradation, especially if the control lagged the other signals. Time shifts in angle of attack, angle of sideslip, and pitch rate affected the estimates less than time shifts in other signals. The lateral-directional rotary derivatives were affected more than the other derivatives by time shifts in any variable.

RECOMMENDATIONS

In specifying a data acquisition system for determining stability and control derivatives, any signal processing that causes time shifts, such as filtering or significant sampling delays, should be avoided. If such signal processing is unavoidable, all signals should be time shifted by the same amount.

Flight Research Center
National Aeronautics and Space Administration
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TABLE 1. - TEST CONDITIONS

Aircraft	Mach number	α, deg	V, m/sec (ft/sec)	$\bar{q}$, kN/m^2 (lb/ft^2)	Characteristic time,[1] sec	Input	Sample rate, sample/sec
Lateral-directional maneuvers							
A (F-8C, supercritical wing)	1.00	2.5	295.66 (970.00)	17.005 (355.00)	2.03	δ_a	25
B (F-111A)	0.87	11.0	280.53 (920.39)	12.272 (256.19)	3.06	δ_r	20
C (JetStar)	0.40	9.7	126.43 (414.80)	3.601 (75.18)	4.32	δ_a	50
D (F-8C)	0.67	5.5	211.56 (694.10)	1.461 (305.10)	2.12	δ_a/δ_r	20
E (M2-F3)	0.66	7.2	197.39 (647.60)	8.114 (169.40)	1.47	$\delta_a/\delta_r/\delta_1$	50
Longitudinal maneuvers							
B (F-111A)	0.87	5.5	274.02 (899.00)	14.705 (307.00)	2.45	δ_e	20
C (JetStar)	0.32	9.1	105.15 (344.99)	5.029 (104.99)	3.31	δ_e	50

[1] The period for the short period mode for longitudinal derivatives or the Dutch roll mode for the lateral-directional derivatives.

TABLE 2.—ZERO TIME-SHIFT DERIVATIVES

Lateral-directional derivatives											
Aircraft	N_β', rad/sec^2	L_β', rad/sec^2	Y_β', rad/sec	N_r', rad/sec	L_r', rad/sec	N_p', rad/sec	L_p', rad/sec	N_{δ_r}', rad/sec^2	L_{δ_r}', rad/sec^2	N_{δ_a}', rad/sec^2	L_{δ_a}', rad/sec^2
A	7.229	-52.590	-0.193	-0.345	-1.388	0.050	-4.235	------	-----	-0.362	20.290
B	0.597	-17.940	-0.020	0.005	3.292	-0.011	-0.709	-1.213	2.522	------	------
C	1.121	-5.855	-0.067	-0.207	0.360	-0.101	-1.169	------	-----	0.062	2.204
D	5.434	-34.960	-0.176	-0.474	2.485	0.016	-2.667	------	-----	0.850	33.175
E	9.021	-70.910	-0.108	-0.660	2.028	0.035	-0.065	-3.059	6.381	0.448	8.584

Longitudinal derivatives					
Aircraft	N_α', rad/sec	M_α', rad/sec^2	M_q', rad/sec	N_{δ_e}', rad/sec	M_{δ_e}', rad/sec^2
B	0.503	-6.597	-0.913	0.012	-9.669
C	0.874	-3.579	-1.020	0.073	-3.995

TABLE 3.—ELEMENTS OF WEIGHTING MATRICES USED IN THE ERROR MINIMIZATION FOR AIRCRAFT A, B, C, D, AND E

Weighting matrices	Signal	Aircraft				
		A	B	C	D	E
Lateral-directional	$\dot{r}$	0	0	0	0	30
	$\dot{p}$	0	0	0	0	40
	a_y	20,000	100,000	19,100	13,040	16,000
	φ	9,750	31,500	86,100	5,864	6,000
	r	280,000	480,000	1,410,000	292,900	120,000
	p	11,500	11,500	66,300	7,475	3,000
	β	2,000,000	250,000	450,000	397,100	800,000
Longitudinal	a_n	---------	3,500	6,300	-------	-------
	θ	---------	1,100,000	2,000,000	-------	-------
	q	---------	130,000	364,000	-------	-------
	α	---------	1,000,000	570,000	-------	-------

TABLE 4.—DERIVATIVES DETERMINED WITH TIME-SHIFTED DATA

(a) Aircraft A, 0.04 second per sample time increment, δ_a maneuver

Time-shift increments (†)	Shifted variable	N_β', rad/sec^2	L_β', rad/sec^2	Y_β', rad/sec	N_r', rad/sec	L_r', rad/sec	N_p', rad/sec	L_p', rad/sec	N_{δ_a}', rad/sec^2	L_{δ_a}', rad/sec^2
0		7.229	-52.590	-.193	-.345	-1.388	.050	-4.235	-.362	20.290
-2	ROLL RATE	7.339	-74.360	-.191	-.335	.221	.064	-7.061	-.419	31.390
-1	ROLL RATE	7.256	-60.860	-.192	-.341	-.563	.054	-5.334	-.377	24.547
+1	ROLL RATE	7.188	-46.750	-.193	-.357	-2.042	.044	-3.437	-.331	17.210
+2	ROLL RATE	7.183	-42.490	-.195	-.368	-2.603	.040	-2.857	-.315	15.010
+5	ROLL RATE	7.222	-32.260	-.199	-.404	-4.368	.030	-1.772	-.273	10.780
+7	ROLL RATE	7.363	-22.820	-.203	-.444	-5.089	.031	-1.405	-.275	9.321
+9	ROLL RATE	7.595	-15.920	-.208	-.464	-5.965	.027	-1.036	-.274	7.925
+10	ROLL RATE	7.617	-11.755	-.205	-.404	-7.046	.021	-1.004	-.277	6.923
-10	ANGLE OF SIDESLIP	8.354	-56.585	-.265	.154	-10.237	.173	-4.229	-.756	19.596
-9	ANGLE OF SIDESLIP	8.228	-55.540	-.253	.075	-9.179	.161	-4.207	-.725	19.677
-8	ANGLE OF SIDESLIP	8.106	-55.026	-.243	.007	-8.180	.148	-4.183	-.687	19.718
-7	ANGLE OF SIDESLIP	8.014	-54.766	-.233	-.054	-7.046	.141	-4.267	-.682	20.225
-5	ANGLE OF SIDESLIP	7.741	-53.700	-.229	-.166	-5.353	.108	-4.149	-.559	19.860
-2	ANGLE OF SIDESLIP	7.406	-52.930	-.202	-.290	-2.809	.070	-4.176	-.430	20.080
-1	ANGLE OF SIDESLIP	7.306	-52.740	-.197	-.321	-2.034	.059	-4.197	-.390	20.160
+1	ANGLE OF SIDESLIP	7.142	-52.300	-.188	-.370	-.724	.040	-4.268	-.324	20.370
+2	ANGLE OF SIDESLIP	7.077	-52.410	-.184	-.391	.066	.032	-4.316	-.296	20.530
+5	ANGLE OF SIDESLIP	6.897	-52.810	-.173	-.437	2.145	.010	-4.460	-.207	20.870
+7	ANGLE OF SIDESLIP	6.823	-53.650	-.160	-.461	3.568	.001	-4.578	-.164	21.130
+8	ANGLE OF SIDESLIP	6.805	-54.280	-.163	-.471	4.278	-.001	-4.644	-.155	21.281
-10	AILERON DEFLECTION	7.258	-29.730	-.192	-.804	2.084	-.091	-.613	-.058	6.843
-9	AILERON DEFLECTION	7.247	-30.200	-.193	-.755	1.818	-.075	-.796	-.107	7.582
-8	AILERON DEFLECTION	7.229	-31.585	-.196	-.711	1.823	-.057	-.992	-.165	8.403
-7	AILERON DEFLECTION	7.231	-33.510	-.198	-.664	1.648	-.038	-1.162	-.213	9.048
-5	AILERON DEFLECTION	7.118	-35.180	-.196	-.558	1.200	-.013	-1.696	-.237	10.860
-2	AILERON DEFLECTION	7.085	-42.100	-.193	-.429	-.264	.021	-2.839	-.281	14.940
-1	AILERON DEFLECTION	7.130	-45.470	-.192	-.390	-.340	.034	-3.427	-.309	17.150
+1	AILERON DEFLECTION	7.386	-61.860	-.193	-.297	-2.928	.071	-5.423	-.446	25.040
+2	AILERON DEFLECTION	7.654	-77.520	-.192	-.237	-5.582	.104	-7.384	-.571	33.090
+3	AILERON DEFLECTION	8.015	-107.000	-.192	-.152	-11.065	.146	-10.880	-.736	47.690

† + corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.

TABLE 4.—DERIVATIVES DETERMINED WITH TIME-SHIFTED DATA - Continued

(b) Aircraft B, 0.05 second per sample time increment, δ_r maneuver

Time-shift increments (†)	Shifted variable	N_β', rad/sec^2	L_β', rad/sec^2	Y_β', rad/sec	N_r', rad/sec	L_r', rad/sec	N_p', rad/sec	L_p', rad/sec	N_{δ_r}', rad/sec^2	L_{δ_r}', rad/sec^2
0		.597	-17.940	-.020	.005	3.292	-.011	-.769	-1.213	2.522
-7	ROLL RATE	.669	-18.980	-.019	.037	5.460	-.030	-.807	-1.184	-.568
-5	ROLL RATE	.590	-18.850	-.020	.024	5.119	-.024	-.791	-1.186	.604
-4	ROLL RATE	.596	-18.620	-.020	.019	4.773	-.022	-.773	-1.196	1.054
-3	ROLL RATE	.596	-18.460	-.019	.014	4.454	-.019	-.759	-1.202	1.470
-2	ROLL RATE	.600	-18.330	-.019	.007	4.142	-.016	-.743	-1.205	1.821
-1	ROLL RATE	.600	-18.140	-.019	.003	3.667	-.013	-.726	-1.212	2.205
+1	ROLL RATE	.606	-17.890	-.020	-.005	2.859	-.008	-.693	-1.214	2.684
+2	ROLL RATE	.611	-17.790	-.020	-.008	2.434	-.006	-.677	-1.214	2.820
+3	ROLL RATE	.614	-17.620	-.020	-.007	1.863	-.003	-.659	-1.227	3.037
+4	ROLL RATE	.619	-17.530	-.020	-.007	1.394	-0.000	-.645	-1.226	3.055
+5	ROLL RATE	.621	-17.390	-.020	-.006	.869	.002	-.628	-1.230	3.051
+7	ROLL RATE	.630	-17.170	-.020	.001	-.205	.007	-.601	-1.236	2.845
+8	ROLL RATE	.635	-17.080	-.020	.004	-.708	.009	-.589	-1.237	2.612
+9	ROLL RATE	.646	-17.025	-.020	.009	-1.322	.011	-.580	-1.237	2.278
+10	ROLL RATE	.649	-16.970	-.020	.009	-1.515	.013	-.569	-1.232	1.853
-5	ANGLE OF SIDESLIP	.562	-18.100	-.020	-.063	3.824	-.004	-.649	-1.171	2.468
-4	ANGLE OF SIDESLIP	.574	-18.050	-.020	-.054	3.688	-.005	-.658	-1.180	2.481
-3	ANGLE OF SIDESLIP	.581	-17.980	-.019	-.042	3.561	-.006	-.669	-1.191	2.521
-2	ANGLE OF SIDESLIP	.588	-17.940	-.019	-.029	3.433	-.007	-.681	-1.202	2.539
-1	ANGLE OF SIDESLIP	.595	-17.930	-.019	-.016	3.321	-.009	-.694	-1.210	2.537
+1	ANGLE OF SIDESLIP	.606	-18.005	-.020	.015	3.127	-.012	-.724	-1.222	2.468
+2	ANGLE OF SIDESLIP	.613	-18.165	-.020	.032	2.997	-.014	-.742	-1.223	2.428
+3	ANGLE OF SIDESLIP	.619	-18.350	-.020	.049	2.993	-.016	-.760	-1.225	2.379
+4	ANGLE OF SIDESLIP	.625	-18.560	-.020	.067	2.897	-.017	-.779	-1.221	2.289
+5	ANGLE OF SIDESLIP	.627	-18.784	-.020	.088	2.717	-.019	-.798	-1.221	2.231
+7	ANGLE OF SIDESLIP	.634	-19.420	-.021	.128	2.517	-.022	-.840	-1.212	2.021
+8	ANGLE OF SIDESLIP	.636	-19.800	-.021	.149	2.400	-.023	-.863	-1.205	1.888
+9	ANGLE OF SIDESLIP	.638	-20.200	-.021	.167	2.398	-.025	-.886	-1.193	1.710
-5	RUDDER DEFLECTION	.337	-19.860	-.020	.124	-1.918	-.009	-.694	-1.057	2.831
-4	RUDDER DEFLECTION	.391	-19.102	-.020	.118	-.656	-.009	-.705	-1.096	3.094
-3	RUDDER DEFLECTION	.447	-18.559	-.019	.095	.432	-.009	-.711	-1.135	3.164
-2	RUDDER DEFLECTION	.499	-18.205	-.020	.068	1.453	-.010	-.714	-1.169	3.080
-1	RUDDER DEFLECTION	.549	-18.007	-.020	.038	2.406	-.010	-.713	-1.195	2.861
+1	RUDDER DEFLECTION	.642	-17.940	-.020	-.030	4.106	-.012	-.697	-1.219	2.094
+2	RUDDER DEFLECTION	.683	-18.060	-.019	-.065	4.845	-.013	-.683	-1.216	1.588
+3	RUDDER DEFLECTION	.729	-18.320	-.019	-.107	5.763	-.015	-.663	-1.206	.921
+4	RUDDER DEFLECTION	.754	-18.500	-.019	-.149	6.478	-.015	-.635	-1.180	.268
+5	RUDDER DEFLECTION	.803	-19.400	-.019	-.160	6.848	-.018	-.626	-1.161	-.495

†+ corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.

TABLE 4.—DERIVATIVES DETERMINED WITH TIME-SHIFTED DATA - Continued

(c) Aircraft C, 0.02 second per sample time increment, δ_a maneuver

Time-shift increments (†)	Shifted variable	N_β', rad/sec^2	L_β', rad/sec^2	Y_β', rad/sec	N_r', rad/sec	L_r', rad/sec	N_p', rad/sec	L_p', rad/sec	N_{δ_a}', rad/sec^2	L_{δ_a}', rad/sec^2
0		1.121	-5.855	-.067	-.207	.360	-.101	-1.169	.062	2.204
-10	ROLL RATE	1.106	-7.630	-.060	-.185	-1.038	-.136	-2.081	.105	2.882
-9	ROLL RATE	1.112	-7.370	-.060	-.186	-.829	-.131	-1.947	.099	2.779
-8	ROLL RATE	1.086	-6.978	-.062	-.137	-.403	-.115	-1.806	.086	2.690
-7	ROLL RATE	1.112	-6.877	-.062	-.169	-.417	-.118	-1.717	.086	2.619
-5	ROLL RATE	1.113	-6.502	-.063	-.175	-.138	-.111	-1.532	.078	2.482
-4	ROLL RATE	1.113	-6.339	-.064	-.180	-.019	-.108	-1.449	.074	2.420
-3	ROLL RATE	1.103	-6.151	-.065	-.171	.155	-.104	-1.376	.069	2.367
-2	ROLL RATE	1.119	-6.096	-.066	-.216	.204	-.108	-1.306	.065	2.321
-1	ROLL RATE	1.116	-5.933	-.066	-.202	.270	-.103	-1.234	.065	2.255
+1	ROLL RATE	1.116	-5.720	-.067	-.209	.484	-.100	-1.106	.061	2.151
+2	ROLL RATE	1.120	-5.699	-.068	-.218	.534	-.099	-1.042	.060	2.100
+3	ROLL RATE	1.119	-5.478	-.067	-.249	.559	-.101	-.993	.058	2.056
+4	ROLL RATE	1.107	-5.428	-.069	-.277	.655	-.105	-.943	.054	2.020
+5	ROLL RATE	1.122	-5.355	-.070	-.299	.717	-.105	-.883	.051	1.967
+7	ROLL RATE	1.134	-5.278	-.071	-.288	.838	-.100	-.773	.053	1.860
+8	ROLL RATE	1.142	-5.266	-.072	-.339	.955	-.109	-.718	.051	1.811
+9	ROLL RATE	1.132	-5.146	-.072	-.353	.969	-.108	-.678	.049	1.777
+10	ROLL RATE	1.128	-5.045	-.073	-.365	1.002	-.107	-.636	.046	1.739
-10	ANGLE OF SIDESLIP	1.087	-5.755	-.086	-.177	.107	-.100	-1.159	.067	2.189
-9	ANGLE OF SIDESLIP	1.088	-5.796	-.085	-.177	.139	-.100	-1.157	.067	2.186
-8	ANGLE OF SIDESLIP	1.089	-5.776	-.082	-.180	.168	-.101	-1.156	.067	2.188
-7	ANGLE OF SIDESLIP	1.086	-5.723	-.080	-.194	.171	-.102	-1.161	.067	2.190
-5	ANGLE OF SIDESLIP	1.097	-5.759	-.077	-.194	.231	-.102	-1.160	.066	2.192
-4	ANGLE OF SIDESLIP	1.095	-5.772	-.074	-.197	.275	-.103	-1.155	.067	2.187
-3	ANGLE OF SIDESLIP	1.101	-5.784	-.072	-.200	.297	-.103	-1.157	.066	2.190
-2	ANGLE OF SIDESLIP	1.104	-5.787	-.070	-.204	.320	-.102	-1.160	.065	2.194
-1	ANGLE OF SIDESLIP	1.114	-5.820	-.069	-.207	.334	-.102	-1.165	.064	2.199
+1	ANGLE OF SIDESLIP	1.118	-5.860	-.065	-.214	.395	-.102	-1.166	.063	2.200
+2	ANGLE OF SIDESLIP	1.122	-5.918	-.064	-.215	.425	-.102	-1.169	.063	2.202
+3	ANGLE OF SIDESLIP	1.138	-5.924	-.061	-.218	.429	-.101	-1.179	.060	2.213
+4	ANGLE OF SIDESLIP	1.143	-5.944	-.059	-.220	.456	-.100	-1.184	.059	2.219
+5	ANGLE OF SIDESLIP	1.146	-5.971	-.057	-.212	.531	-.098	-1.191	.057	2.225
+7	ANGLE OF SIDESLIP	1.171	-6.066	-.053	-.232	.520	-.099	-1.201	.055	2.234
+8	ANGLE OF SIDESLIP	1.179	-6.104	-.051	-.235	.540	-.098	-1.209	.054	2.241
+9	ANGLE OF SIDESLIP	1.189	-6.159	-.055	-.237	.566	-.097	-1.216	.052	2.248
+10	ANGLE OF SIDESLIP	1.203	-6.230	-.048	-.240	.587	-.096	-1.226	.049	2.257
-10	AILERON DEFLECTION	1.079	-4.623	-.069	-.334	1.598	-.114	-.587	.053	1.738
-9	AILERON DEFLECTION	1.097	-4.884	-.068	-.312	1.630	-.112	-.597	.055	1.740
-8	AILERON DEFLECTION	1.100	-4.959	-.068	-.298	1.503	-.110	-.651	.056	1.783
-7	AILERON DEFLECTION	1.105	-5.073	-.067	-.281	1.363	-.108	-.714	.057	1.833
-5	AILERON DEFLECTION	1.118	-5.319	-.067	-.255	1.127	-.105	-.821	.059	1.921
-4	AILERON DEFLECTION	1.115	-5.315	-.067	-.255	.964	-.105	-.888	.059	1.974
-3	AILERON DEFLECTION	1.107	-5.398	-.067	-.237	.823	-.103	-.958	.059	2.034
-2	AILERON DEFLECTION	1.114	-5.503	-.066	-.238	.658	-.104	-1.025	.061	2.086
-1	AILERON DEFLECTION	1.114	-5.720	-.067	-.212	.542	-.101	-1.091	.062	2.142
+1	AILERON DEFLECTION	1.121	-5.964	-.067	-.209	.159	-.103	-1.251	.064	2.266
+2	AILERON DEFLECTION	1.120	-6.061	-.066	-.218	-.097	-.106	-1.350	.068	2.341
+3	AILERON DEFLECTION	1.123	-6.306	-.066	-.202	-.266	-.105	-1.432	.069	2.408
+4	AILERON DEFLECTION	1.120	-6.481	-.066	-.200	-.513	-.107	-1.538	.071	2.494
+5	AILERON DEFLECTION	1.107	-6.644	-.066	-.182	-.676	-.105	-1.648	.071	2.585
+8	AILERON DEFLECTION	1.100	-7.413	-.066	-.198	-1.673	-.116	-2.066	.081	2.927
+10	AILERON DEFLECTION	1.081	-8.150	-.070	-.246	-2.803	-.135	-2.461	.098	3.260

†+ corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.

TABLE 4.—DERIVATIVES DETERMINED WITH TIME-SHIFTED DATA - Continued

(d) Aircraft D, 0.05 second per sample time increment, δ_a and δ_r maneuver

Time-shift increments (†)	Shifted variable	N_β', rad/sec^2	L_β', rad/sec^2	Y_β', rad/sec	N_r', rad/sec	L_r', rad/sec	N_p', rad/sec	L_p', rad/sec	N_{δ_a}', rad/sec^2	L_{δ_a}', rad/sec^2
0		5.434	-34.960	-.176	-.474	2.485	.016	-2.667	.850	33.175
-5	ROLL RATE	5.750	-64.200	-.152	-.332	4.184	-.014	-6.149	1.179	47.468
-4	ROLL RATE	5.660	-59.340	-.157	-.361	3.435	-.007	-5.575	1.126	47.060
-3	ROLL RATE	5.650	-51.490	-.161	-.387	2.956	.003	-4.629	1.031	42.850
-2	ROLL RATE	5.591	-44.588	-.166	-.410	2.667	.010	-3.830	.956	35.058
-1	ROLL RATE	5.514	-39.248	-.171	-.446	2.541	.013	-3.191	.885	35.784
+1	ROLL RATE	5.316	-32.145	-.180	-.542	2.389	.012	-2.275	.780	30.367
+2	ROLL RATE	5.215	-29.403	-.184	-.605	2.225	.008	-1.925	.758	28.470
+3	ROLL RATE	5.153	-27.690	-.188	-.643	2.035	.006	-1.655	.788	26.184
+4	ROLL RATE	5.079	-25.780	-.191	-.681	2.051	.006	-1.396	.790	24.032
+5	ROLL RATE	5.027	-23.760	-.191	-.696	2.241	.006	-1.137	.851	22.110
+7	ROLL RATE	4.960	-21.710	-.194	-.722	1.106	.013	-.914	.992	18.830
+8	ROLL RATE	4.925	-20.450	-.193	-.707	.825	.021	-.796	1.045	17.550
-5	ANGLE OF SIDESLIP	5.500	-37.280	-.189	-.522	2.241	.006	-2.640	.871	32.750
-4	ANGLE OF SIDESLIP	5.458	-36.560	-.185	-.516	2.249	.006	-2.645	.892	32.690
-3	ANGLE OF SIDESLIP	5.433	-36.182	-.182	-.506	2.317	.006	-2.648	.891	32.664
-2	ANGLE OF SIDESLIP	5.418	-35.765	-.179	-.499	2.367	.008	-2.657	.882	32.666
-1	ANGLE OF SIDESLIP	5.409	-35.483	-.178	-.496	2.345	.010	-2.675	.866	32.797
+1	ANGLE OF SIDESLIP	5.438	-35.224	-.175	-.492	2.547	.018	-2.706	.771	33.396
+2	ANGLE OF SIDESLIP	5.471	-35.324	-.175	-.495	2.647	.023	-2.732	.701	33.373
+3	ANGLE OF SIDESLIP	5.519	-35.309	-.175	-.502	2.859	.030	-2.736	.649	33.959
+4	ANGLE OF SIDESLIP	5.593	-35.877	-.175	-.511	3.067	.036	-2.772	.577	34.246
+5	ANGLE OF SIDESLIP	5.616	-35.970	-.176	-.525	3.230	.043	-2.799	.453	34.530
-4	AILERON DEFLECTION	5.360	-24.770	-.177	-.579	5.476	.005	-1.492	.791	25.350
-3	AILERON DEFLECTION	5.412	-26.483	-.178	-.561	5.105	.009	-1.673	.686	26.008
-2	AILERON DEFLECTION	5.398	-29.045	-.177	-.528	4.456	.010	-1.983	.731	28.093
-1	AILERON DEFLECTION	5.428	-31.892	-.177	-.512	3.660	.013	-2.296	.735	30.343
+1	AILERON DEFLECTION	5.342	-39.868	-.175	-.496	.734	.007	-3.216	.967	35.982
+2	AILERON DEFLECTION	5.160	-46.143	-.173	-.538	-1.834	-.011	-4.007	1.177	40.435
+3	AILERON DEFLECTION	4.797	-57.512	-.172	-.634	-6.919	-.049	-5.267	1.553	48.368
+4	AILERON DEFLECTION	4.043	-79.150	-.171	-.888	-13.790	-.132	-7.769	2.191	65.650
+5	AILERON DEFLECTION	2.385	-123.080	-.168	-1.450	-30.340	-.313	-12.710	3.565	101.000

†+ corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.

TABLE 4.– DERIVATIVES DETERMINED WITH TIME-SHIFTED DATA - Continued

(e) Aircraft E, 0.02 second per sample time increment, δ_a and δ_r maneuver

Time-shift increments (†)	Shifted variable	N_β', rad/sec^2	L_β', rad/sec^2	Y_β', rad/sec	N_r', rad/sec	L_r', rad/sec	N_p', rad/sec	L_p', rad/sec	N_{δ_r}', rad/sec^2	L_{δ_r}', rad/sec^2	N_{δ_a}', rad/sec^2	L_{δ_a}', rad/sec^2
0		9.021	-70.910	-.108	-.660	2.028	.035	-.065	-3.059	6.381	.448	8.584
-5	ROLL RATE	9.891	-64.760	-.106	.138	7.109	-.118	-.790	-3.076	6.199	.605	8.907
-2	ROLL RATE	9.368	-69.240	-.108	-.337	4.142	-.031	-.365	-2.988	6.745	.579	8.923
-1	ROLL RATE	9.276	-70.300	-.109	-.502	3.141	-.002	-.206	-2.986	6.695	.548	8.763
+1	ROLL RATE	9.050	-72.070	-.111	-.863	1.009	.059	.125	-3.101	5.876	.423	8.065
+2	ROLL RATE	9.092	-72.360	-.112	-1.025	-.023	.092	.296	-3.169	5.439	.373	7.796
+5	ROLL RATE	9.551	-71.980	-.118	-1.534	-3.157	.186	.832	-3.523	3.256	.201	6.784
-5	ANGLE OF SIDESLIP	10.297	-81.430	-.124	-.923	1.938	.031	.170	-2.992	4.002	.359	8.217
-2	ANGLE OF SIDESLIP	9.589	-74.470	-.114	-.763	2.110	.030	.027	-3.039	5.677	.454	8.427
-1	ANGLE OF SIDESLIP	9.406	-72.830	-.112	-.719	2.133	.028	-.008	-3.035	6.102	.483	8.452
+1	ANGLE OF SIDESLIP	8.907	-70.030	-.108	-.645	1.984	.027	-.085	-3.016	6.553	.493	8.399
+2	ANGLE OF SIDESLIP	8.787	-69.100	-.107	-.606	1.947	.025	-.113	-2.982	6.912	.516	8.431
+5	ANGLE OF SIDESLIP	8.570	-67.950	-.107	-.513	1.939	.017	-.166	-2.831	7.010	.551	8.477
-5	AILERON DEFLECTION	9.706	-71.310	-.112	-.936	1.357	.030	.538	-3.396	3.704	.493	7.329
-2	AILERON DEFLECTION	9.417	-70.330	-.111	-.783	1.795	.028	.183	-3.185	5.243	.490	8.162
-1	AILERON DEFLECTION	9.311	-70.660	-.110	-.731	1.955	.028	.068	-3.107	5.823	.493	8.355
+1	AILERON DEFLECTION	8.958	-72.210	-.109	-.634	2.131	.029	-.158	-2.957	6.906	.480	8.431
+2	AILERON DEFLECTION	8.845	-73.360	-.108	-.576	2.164	.030	-.261	-2.868	7.593	.486	8.439
+5	AILERON DEFLECTION	8.496	-78.470	-.106	-.427	1.949	.033	-.473	-2.600	9.371	.510	7.812
-5	RUDDER DEFLECTION	8.790	-69.210	-.111	-.287	-.581	.075	-.409	-2.884	6.086	.505	8.895
-2	RUDDER DEFLECTION	8.979	-69.670	-.110	-.511	.967	.048	-.220	-2.886	7.051	.497	8.623
-1	RUDDER DEFLECTION	9.082	-70.340	-.110	-.590	1.511	.038	-.139	-2.939	6.917	.499	8.549
+1	RUDDER DEFLECTION	9.270	-72.800	-.110	-.791	2.743	.015	.083	-3.159	5.434	.486	8.264
+2	RUDDER DEFLECTION	9.401	-74.430	-.110	-.893	3.436	.005	.223	-3.298	4.166	.465	8.228
+5	RUDDER DEFLECTION	9.833	-82.070	-.110	-1.273	5.797	-.025	.826	-3.665	-2.169	.290	7.732

†+ corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.

(f) Aircraft B, 0.05 second per sample time increment, δ_e maneuver

Time-shift increments (†)	Shifted variable	N_α', rad/sec	M_α', rad/sec^2	M_q', rad/sec	N_{δ_e}', rad/sec	M_{δ_e}', rad/sec^2
0		.503	-6.597	-.913	.012	-9.669
-5	ANGLE OF ATTACK	.581	-7.112	-.881	.042	-9.880
-2	ANGLE OF ATTACK	.527	-6.807	-.914	.027	-9.906
-1	ANGLE OF ATTACK	.514	-6.703	-.914	.020	-9.812
+1	ANGLE OF ATTACK	.493	-6.493	-.907	.004	-9.447
+2	ANGLE OF ATTACK	.486	-6.387	-.902	-.006	-9.216
+5	ANGLE OF ATTACK	.472	-6.160	-.880	-.030	-8.322
-5	PITCH RATE	.537	-6.980	-.897	.041	-8.008
-2	PITCH RATE	.505	-6.816	-.950	.023	-9.375
-1	PITCH RATE	.501	-6.710	-.939	.018	-9.602
+1	PITCH RATE	.507	-6.487	-.864	.007	-9.504
+2	PITCH RATE	.516	-6.380	-.804	.002	-9.183
+5	PITCH RATE	.557	-6.145	-.600	-.010	-7.670
-5	ELEVATOR DEFLECTION	.561	-5.539	-.391	-.051	-5.457
-2	ELEVATOR DEFLECTION	.519	-5.877	-.725	.044	-8.094
-1	ELEVATOR DEFLECTION	.511	-6.189	-.826	.039	-8.985
+1	ELEVATOR DEFLECTION	.492	-7.083	-.971	-.027	-9.920
+2	ELEVATOR DEFLECTION	.481	-7.598	-.999	-.064	-9.644
+5	ELEVATOR DEFLECTION	.446	-9.196	-1.028	-.127	-7.692

†+ corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.

TABLE 4.—DERIVATIVES DETERMINED WITH TIME-SHIFTED DATA - Concluded

(g) Aircraft C, 0.02 second per sample time interval, δ_e maneuver

Time-shift increments (†)	Shifted variable	N_α, rad/sec	M_α, rad/sec^2	M_q, rad/sec	N_{δ_e}, rad/sec	M_{δ_e}, rad/sec^2
0		.874	-3.579	-1.020	.073	-3.995
-10	ANGLE OF ATTACK	.808	-3.620	-1.485	.113	-4.456
-9	ANGLE OF ATTACK	.807	-3.657	-1.485	.102	-4.510
-8	ANGLE OF ATTACK	.810	-3.643	-1.441	.098	-4.475
-7	ANGLE OF ATTACK	.815	-3.646	-1.403	.094	-4.455
-5	ANGLE OF ATTACK	.829	-3.611	-1.289	.092	-4.332
-4	ANGLE OF ATTACK	.834	-3.618	-1.256	.082	-4.303
-3	ANGLE OF ATTACK	.843	-3.621	-1.204	.078	-4.246
-2	ANGLE OF ATTACK	.853	-3.588	-1.131	.081	-4.144
-1	ANGLE OF ATTACK	.864	-3.592	-1.075	.077	-4.075
+1	ANGLE OF ATTACK	.887	-3.585	-.961	.069	-3.916
+2	ANGLE OF ATTACK	.899	-3.573	-.906	.066	-3.831
+3	ANGLE OF ATTACK	.914	-3.581	-.846	.063	-3.744
+4	ANGLE OF ATTACK	.927	-3.572	-.792	.060	-3.657
+5	ANGLE OF ATTACK	.944	-3.582	-.732	.056	-3.564
+7	ANGLE OF ATTACK	.977	-3.588	-.621	.051	-3.383
+8	ANGLE OF ATTACK	.993	-3.583	-.571	.049	-3.298
+9	ANGLE OF ATTACK	1.013	-3.599	-.513	.046	-3.203
+10	ANGLE OF ATTACK	1.029	-3.596	-.466	.044	-3.121
-10	PITCH RATE	.982	-3.800	-.917	.113	-3.888
-9	PITCH RATE	.968	-3.772	-.949	.107	-3.966
-8	PITCH RATE	.957	-3.747	-.958	.105	-3.974
-7	PITCH RATE	.948	-3.731	-.949	.104	-3.917
-5	PITCH RATE	.926	-3.687	-.967	.097	-3.928
-4	PITCH RATE	.914	-3.660	-.992	.091	-3.995
-3	PITCH RATE	.904	-3.641	-1.000	.087	-3.997
-2	PITCH RATE	.893	-3.619	-1.007	.083	-3.998
-1	PITCH RATE	.884	-3.600	-1.014	.078	-3.997
+1	PITCH RATE	.865	-3.563	-1.012	.071	-3.932
+2	PITCH RATE	.855	-3.542	-1.018	.066	-3.927
+3	PITCH RATE	.846	-3.525	-1.024	.060	-3.922
+4	PITCH RATE	.836	-3.503	-1.029	.055	-3.916
+5	PITCH RATE	.828	-3.487	-1.035	.049	-3.909
+7	PITCH RATE	.811	-3.449	-1.045	.038	-3.892
+8	PITCH RATE	.802	-3.428	-1.050	.033	-3.883
+9	PITCH RATE	.794	-3.412	-1.054	.027	-3.872
+10	PITCH RATE	.786	-3.390	-1.069	.019	-3.918
-10	ELEVATOR DEFLECTION	1.006	-3.102	-.326	.010	-2.704
-9	ELEVATOR DEFLECTION	.990	-3.108	-.388	.024	-2.841
-8	ELEVATOR DEFLECTION	.974	-3.135	-.456	.037	-2.946
-7	ELEVATOR DEFLECTION	.961	-3.157	-.517	.048	-3.089
-5	ELEVATOR DEFLECTION	.935	-3.236	-.651	.065	-3.345
-4	ELEVATOR DEFLECTION	.922	-3.296	-.723	.070	-3.455
-3	ELEVATOR DEFLECTION	.910	-3.346	-.790	.074	-3.609
-2	ELEVATOR DEFLECTION	.898	-3.423	-.867	.075	-3.721
-1	ELEVATOR DEFLECTION	.886	-3.486	-.938	.076	-3.881
+1	ELEVATOR DEFLECTION	.862	-3.656	-1.094	.075	-4.158
+2	ELEVATOR DEFLECTION	.849	-3.767	-1.182	.065	-4.274
+3	ELEVATOR DEFLECTION	.837	-3.858	-1.262	.059	-4.440
+4	ELEVATOR DEFLECTION	.823	-3.986	-1.356	.050	-4.557
+5	ELEVATOR DEFLECTION	.810	-4.091	-1.440	.042	-4.724
+7	ELEVATOR DEFLECTION	.780	-4.357	-1.631	.021	-5.005
+8	ELEVATOR DEFLECTION	.764	-4.523	-1.741	.009	-5.119
+9	ELEVATOR DEFLECTION	.748	-4.655	-1.834	-.003	-5.279
+10	ELEVATOR DEFLECTION	.729	-4.840	-1.950	-.016	-5.395

†+ corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.

TABLE 5.—PERCENTAGE OF CHANGE IN LATERAL-DIRECTIONAL DERIVATIVES FOR 0.1-SECOND TIME SHIFT

	Time-shifted variables							
	Time lag				Time lead			
Aircraft	p	β	δ_a	δ_r	p	β	δ_a	δ_r
				N_β				
A	1.38	2.76	-7.93		-2.07	-2.76	2.76	
B	.83	2.50		15.00	-.83	-3.33		-15.83
C	0.00	2.68	.89		0.00	-2.68	-.89	
D	-3.23	1.84	-5.53		2.76	0.00	0.00	
E	5.56	-4.72	-5.28	8.89	11.00	14.44	7.78	-2.22
				L_β				
A	22.86	0.00	-79.05		-83.81	-1.43	21.90	
B	1.41	-1.97		-1.97	-2.54	0.00		-2.54
C	9.40	-1.71	-14.96		-11.97	1.71	11.11	
D	15.00	0.00	-35.00		-26.43	-1.43	18.57	
E	0.00	4.25	-9.86	-15.49	8.45	-15.49	0.00	2.82
				Y_β				
A	-1.77	5.19	.52		.73	-6.49	-1.30	
B	-1.28	-1.74		1.28	.72	.72		-.72
C	-4.48	14.18	1.49		4.85	-13.81	0.00	
D	-1.00	0.00	.08		1.00	-.49	-.14	
E	-9.26	1.85	1.85	-.93	1.85	-11.11	-3.24	-2.78
				N_r				
A	-7.25	-17.39	42.75		4.35	21.74	-36.23	
B	-200.00	1200.00		-2600.00	300.00	-1200.00		2800.00
C	-33.33	-7.38	-2.38		16.67	11.43	-23.81	
D	-22.22	-.51	-7.07		16.16	-.51	-7.07	
E	-123.08	23.07	34.62	-92.31	123.08	-42.31	-42.31	53.84
				L_r				
A	-92.86	132.14	460.71		103.57	-125.00	-135.71	
B	-27.48	-6.11		48.85	24.43	6.11		-54.20
C	102.78	36.11	-250.00		-138.89	-36.11	205.56	
D	-6.12	12.24	-173.47		10.20	-2.04	81.63	
E	-260.00	0.00	0.00	190.00	260.00	0.00	-35.00	-130.00

TABLE 5.—PERCENTAGE OF CHANGE IN LATERAL-DIRECTIONAL DERIVATIVES FOR 0.1-SECOND TIME SHIFT - Concluded

Time-shifted variables								
	Time lag				Time lead			
Aircraft	p	β	δ_a	δ_r	p	β	δ_a	δ_r
				N_p				
A	-27.00	-48.00	140.00		36.00	54.00	-68.00	
B	51.16	-27.91		-20.93	-51.16	27.91		9.30
C	-.99	1.97	-19.21		-9.85	0.00	-9.36	
D	-40.63	43.75	-162.50		-40.63	-46.88	-28.13	
E	600.00	-40.00	-10.00	-240.00	-600.00	-10.00	-10.00	-80.00
				L_p				
A	38.82	-2.35	-125.88		-103.53	1.18	38.82	
B	4.93	-4.93		3.52	-4.58	3.52		0.00
C	24.79	-1.71	-41.88		-31.62	0.00	46.15	
D	28.70	-1.85	-50.00		-42.59	1.85	26.85	
E	1500.00	-66.67	-750.00	1500.00	-1300.00	416.67	100.00	-541.67
				N_{δ_r}				
A								
B	-.99	-1.65		0.00	.41	1.07		3.31
C								
D								
E	-14.75	6.55	14.75	-19.67	-.82	1.64	-11.48	5.73
				L_{δ_r}				
A								
B	13.23	-3.96		-37.62	-26.73	0.00		21.78
C								
D								
E	-49.21	11.11	47.61	-134.92	-1.59	-36.51	-42.86	-1.59
				N_{δ_a}				
A	15.97	22.22	-80.56		-22.92	-25.69	25.00	
B								
C	-17.60	-7.60	22.40		24.00	7.20	-6.40	
D	-12.35	-17.06	39.41		13.53	2.94	-16.47	
E	-111.11	44.44	24.44	-71.11	66.67	-40.00	17.78	24.44
				L_{δ_a}				
A	-29.63	.69	92.59		98.77	-1.23	-29.63	
B								
C	-10.91	.91	17.27		12.73	0.00	-12.73	
D	-14.39	1.52	21.21		15.91	-1.52	-15.15	
E	-20.93	-1.16	-9.30	-9.30	3.49	-4.65	-15.12	3.49

TABLE 6.—PERCENTAGE OF CHANGE IN LONGITUDINAL DERIVATIVES FOR 0.1-SECOND TIME SHIFT

Aircraft	Time-shifted variables					
	Time lag			Time lead		
	α	q	δ_e	α	q	δ_e
	N_α					
B	-3.96	1.98	-4.95	4.95	-.99	4.95
C	8.02	-5.15	-7.45	-4.87	6.01	7.45
	M_α					
B	3.03	3.03	-15.15	-3.03	-3.03	10.23
C	0.00	2.80	-14.69	-1.05	-3.19	9.48
	M_q					
B	.55	10.99	-9.34	-.55	-4.67	18.68
C	27.45	-1.96	-41.18	-27.45	3.92	35.78
	N_{δ_e}					
B	-150.00	-83.33	-641.67	125.00	91.67	275.00
C	-22.60	-31.51	-43.15	21.92	30.14	-12.33
	M_{δ_e}					
B	4.64	5.67	.52	-2.06	4.12	2.06
C	10.68	1.88	-18.57	-8.79	.35	18.33

TABLE 7.—EFFECT OF 0.1-SECOND TIME SHIFTS ON LATERAL-DIRECTIONAL DERIVATIVES

Derivatives	Signals resulting in change in derivative of –		
	Less than 10 percent	10 percent to 25 percent	Greater than 25 percent
Static –			
N_β	p, β, δ_a	δ_r	-----
L_β	β, δ_r	p, δ_a	-----
Y_β	p, β, δ_a, δ_r	-----	-----
Rotary –			
N_r	-----	β	p, δ_r, δ_a
L_r	-----	β	p, δ_r, δ_a
N_p	-----	-----	p, β, δ_a, δ_r
L_p	β, δ_r	-----	p, δ_a
Control –			
N_{δ_r}	p, β, δ_r	δ_a	-----
L_{δ_r}	-----	p, β	δ_a, δ_r
N_{δ_a}	-----	p, β, δ_a	δ_r
L_{δ_a}	β, δ_r	p, δ_a	-----

TABLE 8.—EFFECT OF 0.1-SECOND TIME SHIFTS ON LONGITUDINAL DERIVATIVES

Derivatives	Signals resulting in change in derivative of –		
	Less than 10 percent	10 percent to 25 percent	Greater than 25 percent
Static –			
N_α	α, q, δ_e	-----	-----
M_α	α, q	δ_e	-----
Rotary –			
M_q	q	α	δ_e
Control –			
N_{δ_e}	-----	-----	α, q, δ_e
M_{δ_e}	α, q	δ_e	-----

TABLE 9.—PERCENTAGE OF CHANGE IN LATERAL-DIRECTIONAL DERIVATIVES FOR TIME SHIFT OF 5 PERCENT OF AIRCRAFT CHARACTERISTIC TIME

	Time-shifted variables							
	Time lag				Time lead			
Aircraft	p	β	δ_a	δ_r	p	β	δ_a	δ_r
				N_β				
A	1.38	2.76	-7.93		-2.07	-2.76	2.76	
B	2.52	3.36		22.69	0.00	-3.36		-24.37
C	.90	7.21	-1.80		-.90	-1.80	-1.80	
D	-3.23	1.84	-5.53		2.76	0.00	0.00	
E	4.44	-4.44	-5.56	7.78	5.56	11.67	5.56	-2.78
				L_β				
A	22.86	0.00	-79.05		-83.81	-1.43	21.90	
B	1.41	-4.23		-4.23	-4.23	-1.41		-5.63
C	11.97	-7.69	-40.17		-31.62	1.28	17.95	
D	15.00	0.00	-35.00		-26.43	-1.43	18.57	
E	0.00	2.82	-7.04	-11.27	6.34	-12.68	-1.41	2.82
				Y_β				
A	-1.77	5.19	.52		.73	-6.49	-1.30	
B	-.72	-2.15		2.56	0.00	-.72		-1.28
C	-8.96	29.10	-4.48		8.96	-29.10	-2.99	
D	-1.00	0.00	.08		1.00	-.49	-.14	
E	-6.48	1.85	1.85	-1.85	1.62	-10.19	-4.16	-2.78
				N_r				
A	-7.25	-17.39	42.75		4.35	21.74	-36.23	
B	-300.00	1800.00		-4400.00	400.00	-1600.00		3600.00
C	-78.31	-15.66	-61.45		10.84	14.46	-61.45	
D	-22.22	-.51	-7.07		16.16	-.51	-7.07	
E	-96.30	18.52	25.93	-66.67	88.89	-25.93	-25.93	44.44
				L_r				
A	-92.86	132.14	460.71		103.57	-125.00	-135.71	
B	-42.75	-10.96		61.07	36.64	9.16		-85.59
C	177.78	33.33	-877.78		-400.00	-77.78	350.00	
D	-6.12	12.24	-173.47		10.20	-2.04	81.63	
E	-197.50	-5.00	5.00	140.00	190.00	5.00	-25.00	-105.00

TABLE 9.—PERCENTAGE OF CHANGE IN LATERAL-DIRECTIONAL DERIVATIVES FOR TIME SHIFT OF 5 PERCENT OF AIRCRAFT CHARACTERISTIC TIME - Concluded

	Time-shifted variables							
	Time lag				Time lead			
Aircraft	p	β	δ_a	δ_r	p	β	δ_a	δ_r
				N_p				
A	-27.00	-48.00	140.00		36.00	54.00	-68.00	
B	75.00	-40.91		-31.82	-77.27	40.91		13.64
C	-8.91	5.45	-40.59		-33.66	.99	-14.85	
D	-40.63	43.75	-162.50		-40.63	-46.88	-28.13	
E	328.57	-42.86	-21.42	-142.86	-357.14	-21.42	-21.42	85.71
				L_p				
A	38.82	-2.35	-125.38		-103.53	1.18	38.82	
B	7.04	5.63		7.04	-7.04	5.28		0.00
C	49.15	-3.39	-110.17		-77.97	0.00	54.24	
D	28.70	-1.85	-50.00		-42.59	1.85	26.85	
E	866.67	-66.67	-400.00	866.67	-766.67	233.33	600.00	-366.67
				N_{δ_r}				
A								
B	-1.65	-1.65		.83	.83	1.65		4.90
C								
D								
E	-11.47	4.92	10.66	-14.75	.82	1.64	-9.02	6.56
				L_{δ_r}				
A								
B	18.81	-.59		-63.37	-56.44	0.00		24.75
C								
D								
E	-36.51	9.52	34.92	-96.83	3.17	-25.40	-33.33	4.76
				N_{δ_a}				
A	15.97	22.22	-80.56		-22.92	-25.69	25.00	
B								
C	-29.40	-21.60	58.40		68.00	6.40	-16.00	
D	-12.35	-17.60	39.41		13.53	2.94	-16.47	
E	-37.78	17.78	10.00	-17.78	33.33	-11.11	7.78	12.22
				L_{δ_a}				
A	-29.63	.69	92.59		98.77	-1.23	-29.63	
B								
C	-20.91	1.82	50.91		26.36	-1.82	-22.73	
D	-14.39	1.52	21.21		15.91	-1.52	-15.15	
E	-16.27	-1.16	-5.81	-9.30	4.65	-4.65	-9.30	2.33

TABLE 10.—PERCENTAGE OF CHANGE IN LONGITUDINAL DERIVATIVES FOR TIME SHIFT OF 5 PERCENT OF AIRCRAFT CHARACTERISTIC TIME

	Time-shifted variables					
	Time lag			Time lead		
Aircraft	α	q	δ_e	α	q	δ_e
			N_α			
B	-4.00	4.00	-5.00	6.00	-4.50	4.00
C	14.28	-9.14	-13.71	-8.00	10.29	12.00
			M_α			
B	4.17	4.17	-17.42	-4.55	-4.55	12.12
C	-.39	4.20	-28.67	-1.68	-5.59	12.87
			M_q			
B	1.10	14.84	-10.44	-.54	-4.95	25.27
C	41.09	-1.49	-57.92	-41.58	3.71	58.91
			N_{δ_e}			
B	-183.33	-100.00	-758.33	150.00	116.67	191.67
C	-35.62	-60.27	-95.89	34.25	47.94	-57.53
			M_{δ_e}			
B	5.15	7.47	2.58	-2.32	6.19	20.10
C	19.50	1.89	-30.82	-12.58	1.26	27.04

TABLE 11.—CONFIDENCE LEVELS FOR TIME-SHIFTED CASES

(a) Aircraft E, 0.02 second per sample time increment, δ_a and δ_r maneuver

Time-shift increments (†)	Shifted variable	N_{β}', rad/sec^2	L_{β}', rad/sec^2	Y_{β}', rad/sec	N_r', rad/sec	L_r', rad/sec	N_p', rad/sec	L_p', rad/sec	N_{δ_r}', rad/sec^2	L_{δ_r}', rad/sec^2	N_{δ_a}', rad/sec^2	L_{δ_a}', rad/sec^2
0		.690	4.687	.024	.151	1.125	.032	.172	.452	2.277	.157	.830
-5	ROLL RATE	1.758	10.817	.059	.399	2.566	.091	.467	1.087	5.765	.414	2.385
-2	ROLL RATE	.980	6.464	.033	.220	1.562	.047	.252	.608	3.168	.227	1.274
-1	ROLL RATE	.850	5.638	.028	.185	1.347	.039	.213	.523	2.690	.194	1.065
+1	ROLL RATE	.690	4.591	.023	.139	1.065	.031	.164	.417	2.082	.150	.783
+2	ROLL RATE	.715	4.682	.023	.140	1.062	.031	.166	.418	2.059	.154	.768
+5	ROLL RATE	1.218	7.361	.034	.209	1.502	.052	.258	.626	3.038	.244	1.073
-5	ANGLE OF SIDESLIP	1.784	12.686	.057	.371	2.883	.072	.440	.916	5.188	.351	1.966
-2	ANGLE OF SIDESLIP	1.067	7.253	.035	.224	1.687	.047	.263	.619	3.253	.229	1.250
-1	ANGLE OF SIDESLIP	.894	6.012	.029	.187	1.402	.040	.219	.533	2.755	.194	1.058
+1	ANGLE OF SIDESLIP	.661	4.385	.022	.142	1.023	.031	.162	.416	2.075	.151	.804
+2	ANGLE OF SIDESLIP	.661	4.363	.023	.139	1.037	.031	.161	.419	2.075	.152	.808
+5	ANGLE OF SIDESLIP	1.042	6.837	.036	.214	1.603	.047	.245	.652	3.231	.238	1.268
-5	AILERON DEFLECTION	1.091	7.018	.037	.213	1.581	.042	.219	.606	3.155	.221	1.119
-2	AILERON DEFLECTION	.819	5.338	.027	.168	1.221	.034	.184	.479	2.450	.177	.922
-1	AILERON DEFLECTION	.771	5.071	.026	.161	1.174	.034	.181	.459	2.340	.170	.897
+1	AILERON DEFLECTION	.755	5.118	.025	.160	1.227	.035	.192	.476	2.401	.170	.933
+2	AILERON DEFLECTION	.807	5.532	.027	.174	1.354	.039	.214	.513	2.582	.185	1.028
+5	AILERON DEFLECTION	1.104	7.837	.035	.239	2.025	.057	.320	.705	3.552	.255	1.472
-5	RUDDER DEFLECTION	.836	5.691	.029	.169	1.285	.039	.215	.514	2.627	.192	1.061
-2	RUDDER DEFLECTION	.637	4.256	.021	.134	.990	.029	.160	.398	1.991	.146	.790
-1	RUDDER DEFLECTION	.666	4.433	.022	.141	1.038	.031	.165	.412	2.070	.152	.815
+1	RUDDER DEFLECTION	.868	5.763	.028	.180	1.359	.038	.207	.508	2.619	.187	1.008
+2	RUDDER DEFLECTION	1.042	6.936	.033	.216	1.642	.045	.245	.581	3.070	.220	1.184
+5	RUDDER DEFLECTION	1.646	11.362	.049	.339	2.777	.066	.376	.772	4.446	.315	1.721

†+ corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.

(b) Aircraft B, 0.05 second per sample time increment, δ_e maneuver

Time-shift increments (†)	Shifted variable	N_{α}', rad/sec	M_{α}', rad/sec	M_q', rad/sec	N_{δ_e}', rad/sec	M_{δ_e}', rad/sec
0		.038	.155	.102	.039	.615
-5	ANGLE OF ATTACK	.184	.769	.476	.181	2.888
-2	ANGLE OF ATTACK	.071	.305	.190	.071	1.101
-1	ANGLE OF ATTACK	.046	.195	.124	.047	.721
+1	ANGLE OF ATTACK	.052	.215	.138	.053	.816
+2	ANGLE OF ATTACK	.066	.275	.178	.067	1.017
+5	ANGLE OF ATTACK	.160	.687	.420	.150	2.035
-5	PITCH RATE	.239	1.010	.635	.199	3.196
-2	PITCH RATE	.086	.376	.237	.084	1.335
-1	PITCH RATE	.049	.209	.132	.049	.770
+1	PITCH RATE	.075	.302	.195	.078	1.174
+2	PITCH RATE	.109	.423	.275	.113	1.665
+5	PITCH RATE	.218	.782	.479	.199	2.437
-5	ELEVATOR DEFLECTION	.370	1.132	.692	.274	2.747
-2	ELEVATOR DEFLECTION	.116	.431	.279	.114	1.478
-1	ELEVATOR DEFLECTION	.070	.277	.179	.071	1.017
+1	ELEVATOR DEFLECTION	.063	.276	.173	.063	1.041
+2	ELEVATOR DEFLECTION	.121	.554	.336	.114	1.960
+5	ELEVATOR DEFLECTION	.501	2.538	1.347	.331	6.041

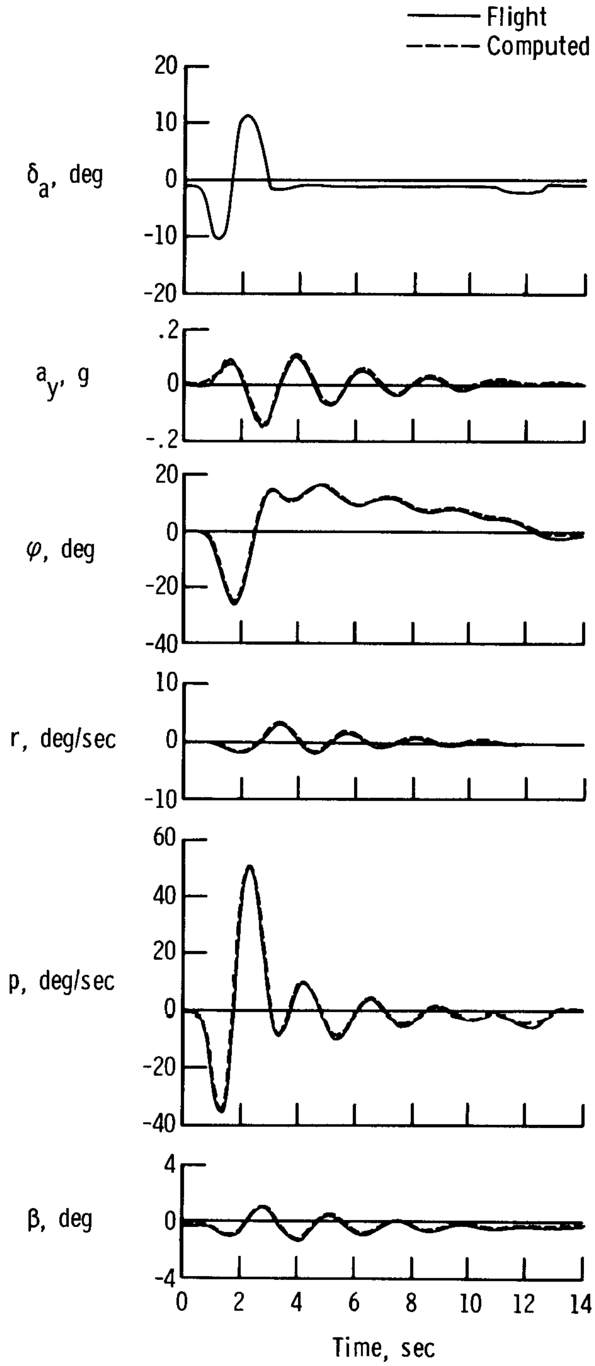
†+ corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.

TABLE 11.—CONFIDENCE LEVELS FOR TIME-SHIFTED CASES - Concluded

(c) Aircraft C, 0.02 second per sample time increment, δ_e maneuver

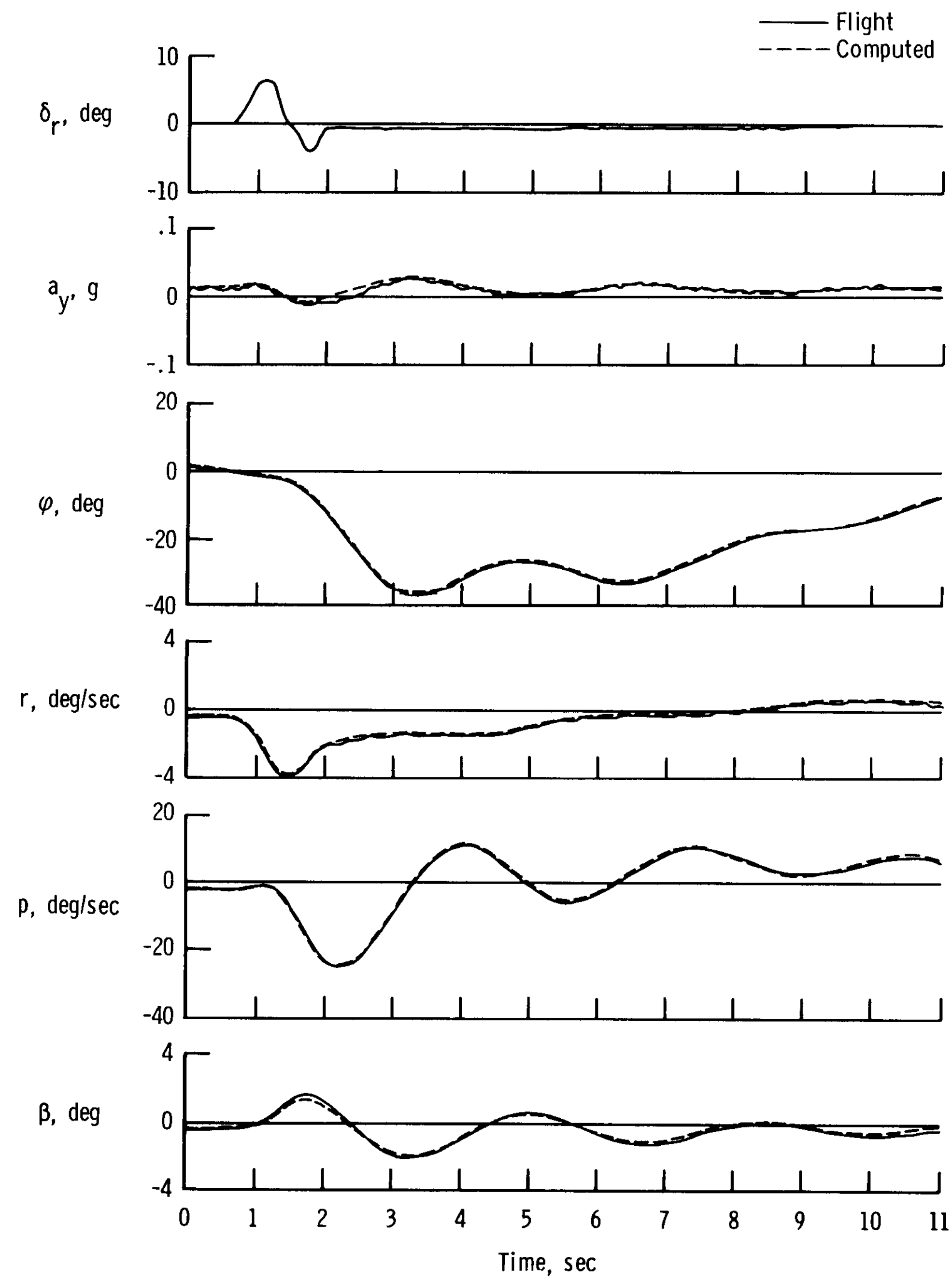
Time-shift increments (†)	Shifted variable	N_α, rad/sec	M_α, rad/sec	M_q, rad/sec	N_{δ_e}, rad/sec	M_{δ_e}, rad/sec
0		.080	.198	.167	.056	.241
-10	ANGLE OF ATTACK	.256	.697	.656	.180	.941
-9	ANGLE OF ATTACK	.231	.628	.583	.162	.847
-8	ANGLE OF ATTACK	.208	.559	.515	.147	.751
-7	ANGLE OF ATTACK	.182	.488	.445	.129	.651
-5	ANGLE OF ATTACK	.064	.357	.319	.136	.467
-4	ANGLE OF ATTACK	.120	.311	.274	.085	.402
-3	ANGLE OF ATTACK	.102	.261	.227	.072	.334
-2	ANGLE OF ATTACK	.086	.218	.188	.061	.274
-1	ANGLE OF ATTACK	.079	.199	.169	.056	.245
+1	ANGLE OF ATTACK	.091	.224	.186	.063	.265
+2	ANGLE OF ATTACK	.104	.253	.207	.071	.294
+3	ANGLE OF ATTACK	.126	.304	.245	.085	.343
+4	ANGLE OF ATTACK	.144	.345	.274	.097	.381
+5	ANGLE OF ATTACK	.171	.406	.316	.113	.434
+7	ANGLE OF ATTACK	.221	.518	.390	.142	.520
+8	ANGLE OF ATTACK	.243	.567	.421	.154	.552
+9	ANGLE OF ATTACK	.274	.637	.464	.170	.597
+10	ANGLE OF ATTACK	.297	.689	.494	.181	.625
-10	PITCH RATE	.155	.387	.311	.101	.432
-9	PITCH RATE	.145	.366	.294	.096	.410
-8	PITCH RATE	.134	.338	.273	.090	.383
-7	PITCH RATE	.122	.303	.249	.082	.349
-5	PITCH RATE	.104	.257	.213	.07[illegible]	.301
-4	PITCH RATE	.098	.244	.202	.067	.287
-3	PITCH RATE	.091	.226	.188	.062	.268
-2	PITCH RATE	.086	.213	.178	.059	.255
-1	PITCH RATE	.082	.203	.170	.057	.244
+1	PITCH RATE	.079	.193	.165	.055	.237
+2	PITCH RATE	.081	.198	.170	.057	.245
+3	PITCH RATE	.084	.205	.176	.059	.254
+4	PITCH RATE	.089	.216	.187	.062	.271
+5	PITCH RATE	.094	.229	.199	.065	.288
+7	PITCH RATE	.108	.261	.229	.076	.332
+8	PITCH RATE	.116	.280	.246	.082	.358
+9	PITCH RATE	.123	.299	.263	.088	.382
+10	PITCH RATE	.131	.319	.280	.094	.407
-10	ELEVATOR DEFLECTION	.313	.682	.488	.190	.586
-9	ELEVATOR DEFLECTION	.284	.620	.455	.178	.564
-8	ELEVATOR DEFLECTION	.254	.557	.420	.162	.529
-7	ELEVATOR DEFLECTION	.227	.501	.386	.148	.520
-5	ELEVATOR DEFLECTION	.174	.390	.312	.117	.421
-4	ELEVATOR DEFLECTION	.148	.337	.274	.100	.373
-3	ELEVATOR DEFLECTION	.125	.289	.238	.086	.332
-2	ELEVATOR DEFLECTION	.103	.245	.204	.071	.286
-1	ELEVATOR DEFLECTION	.088	.213	.178	.062	.255
+1	ELEVATOR DEFLECTION	.082	.210	.177	.058	.260
+2	ELEVATOR DEFLECTION	.095	.250	.212	.067	.311
+3	ELEVATOR DEFLECTION	.114	.309	.262	.081	.390
+4	ELEVATOR DEFLECTION	.139	.388	.328	.097	.488
+5	ELEVATOR DEFLECTION	.165	.476	.401	.116	.534
+7	ELEVATOR DEFLECTION	.223	.692	.578	.155	.874
+8	ELEVATOR DEFLECTION	.255	.824	.683	.174	1.025
+9	ELEVATOR DEFLECTION	.286	.959	.790	.195	1.192
+10	ELEVATOR DEFLECTION	.320	1.119	.913	.241	1.365

†+ corresponds to a time lag, - to a time lead; integer indicates the number of sample time increments of the shift.



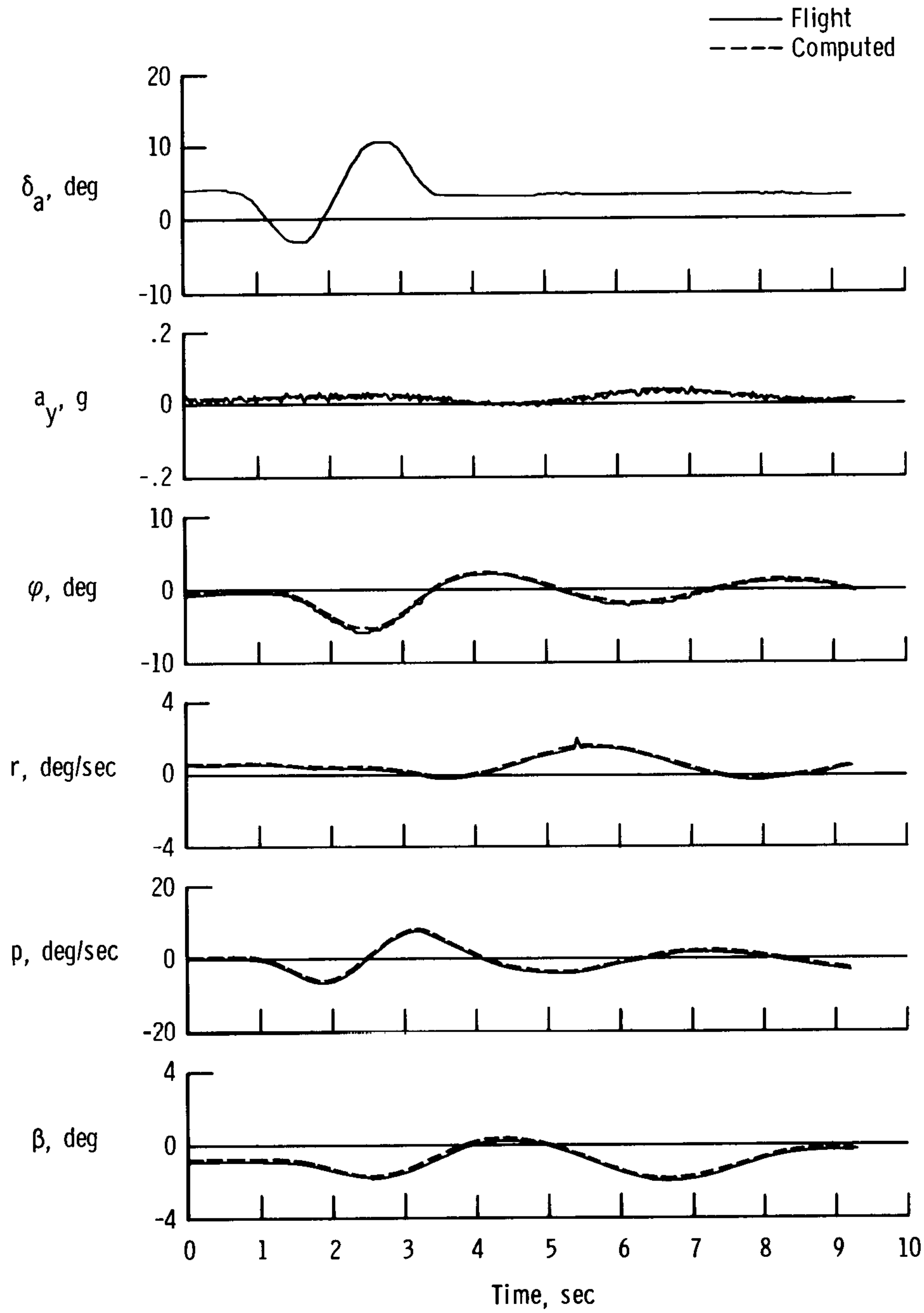
(a) Aircraft A; δ_a pulse.

Figure 1. Typical match between computed and flight time histories for lateral-directional maneuvers with no time shift.



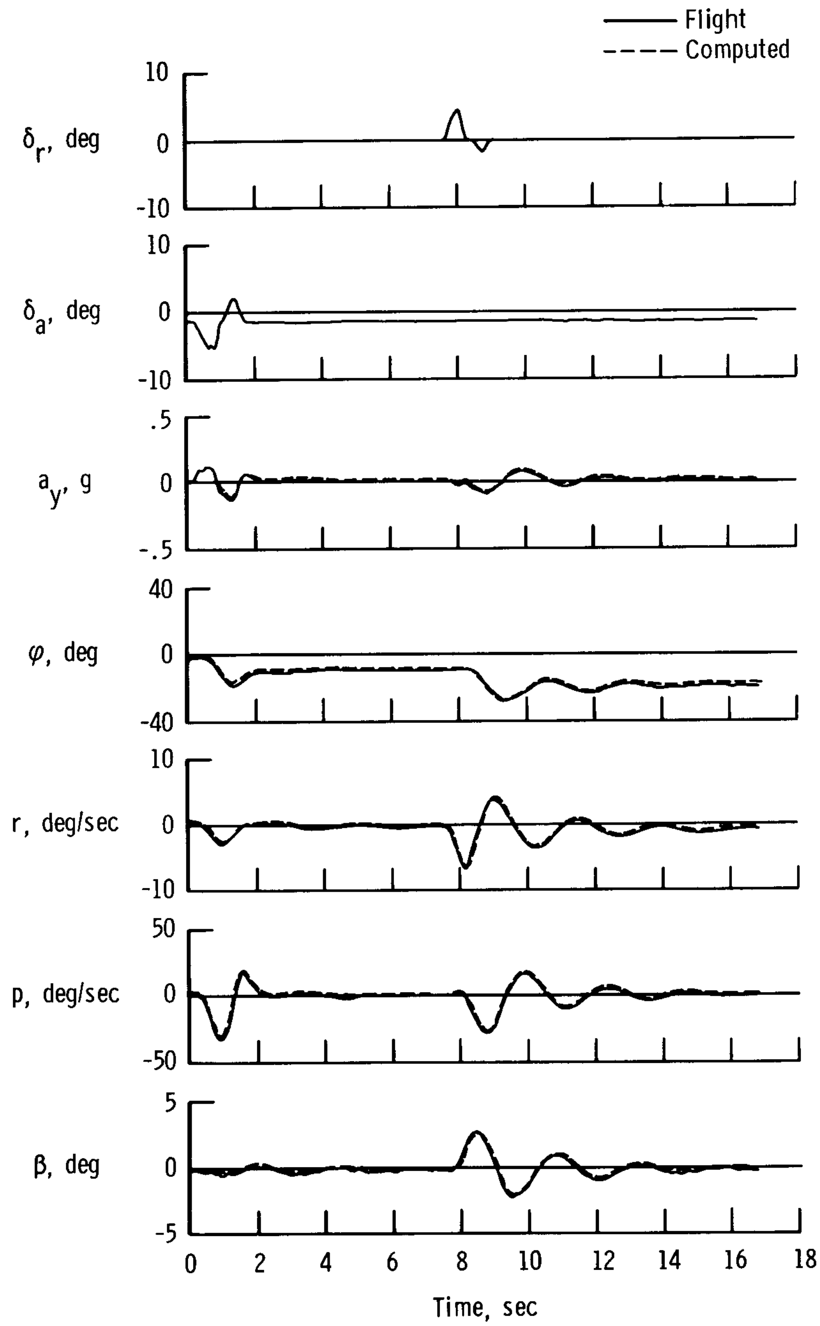
(b) Aircraft B; δ_r pulse.

Figure 1. Continued.



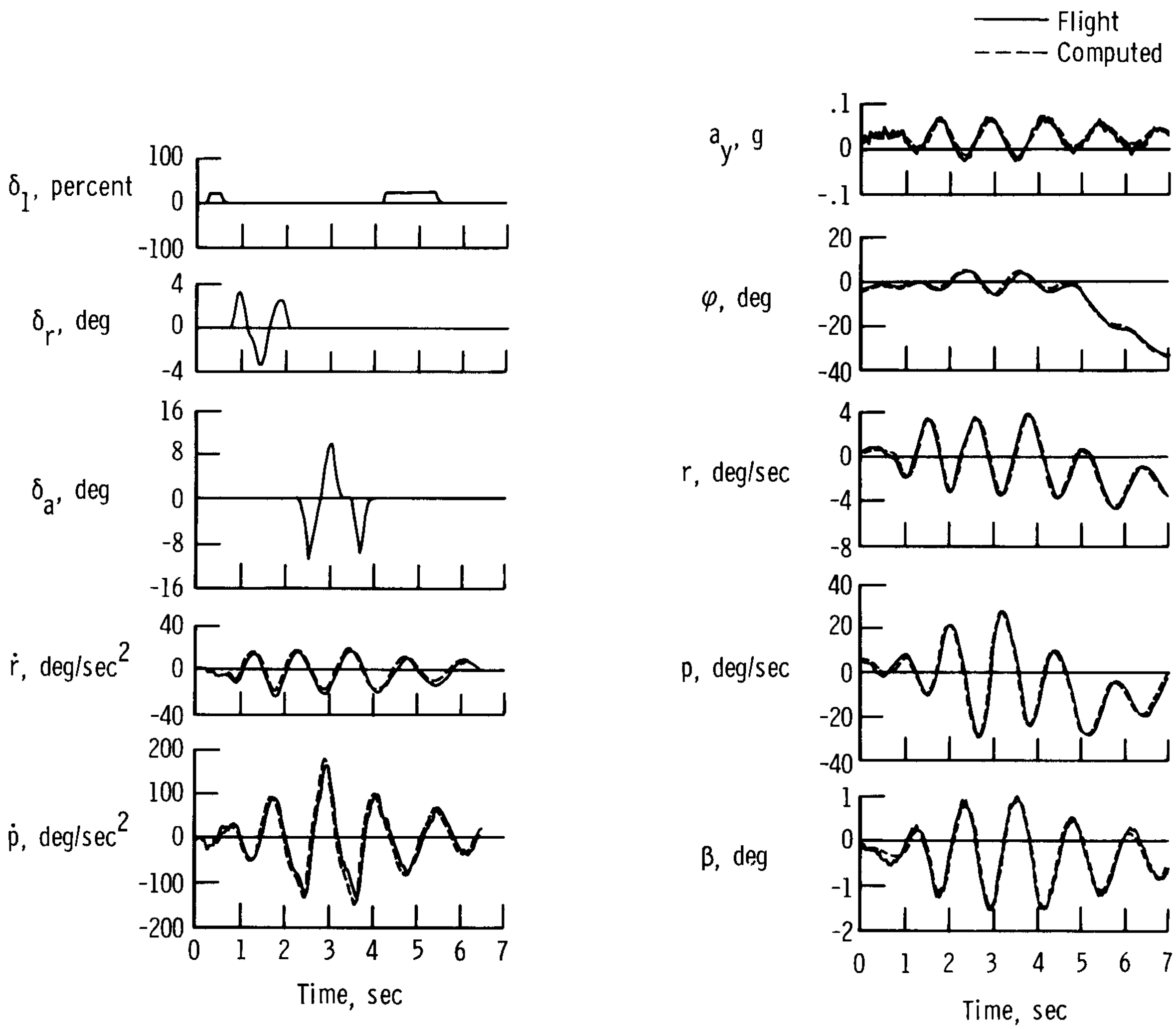
(c) Aircraft C; δ_a pulse.

Figure 1. Continued.



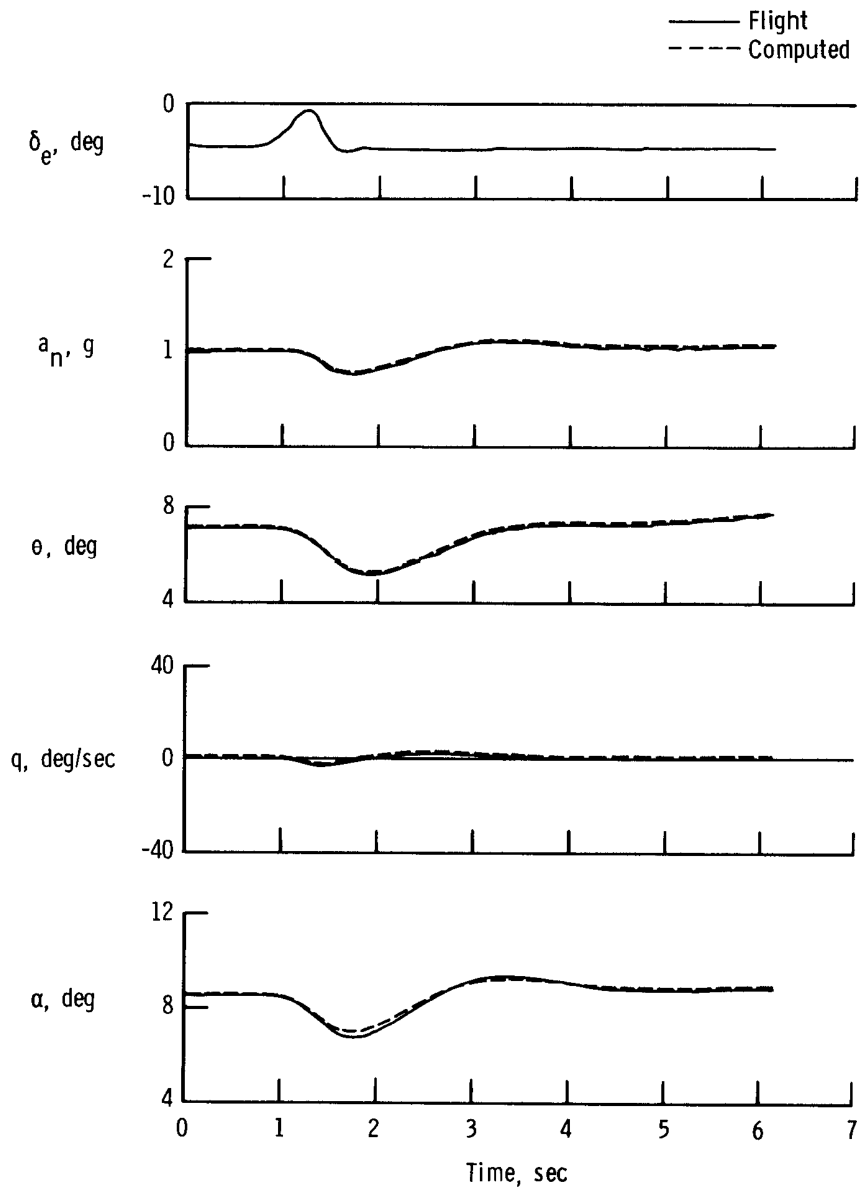
(d) Aircraft D; δ_a and δ_r pulse.

Figure 1. Continued.



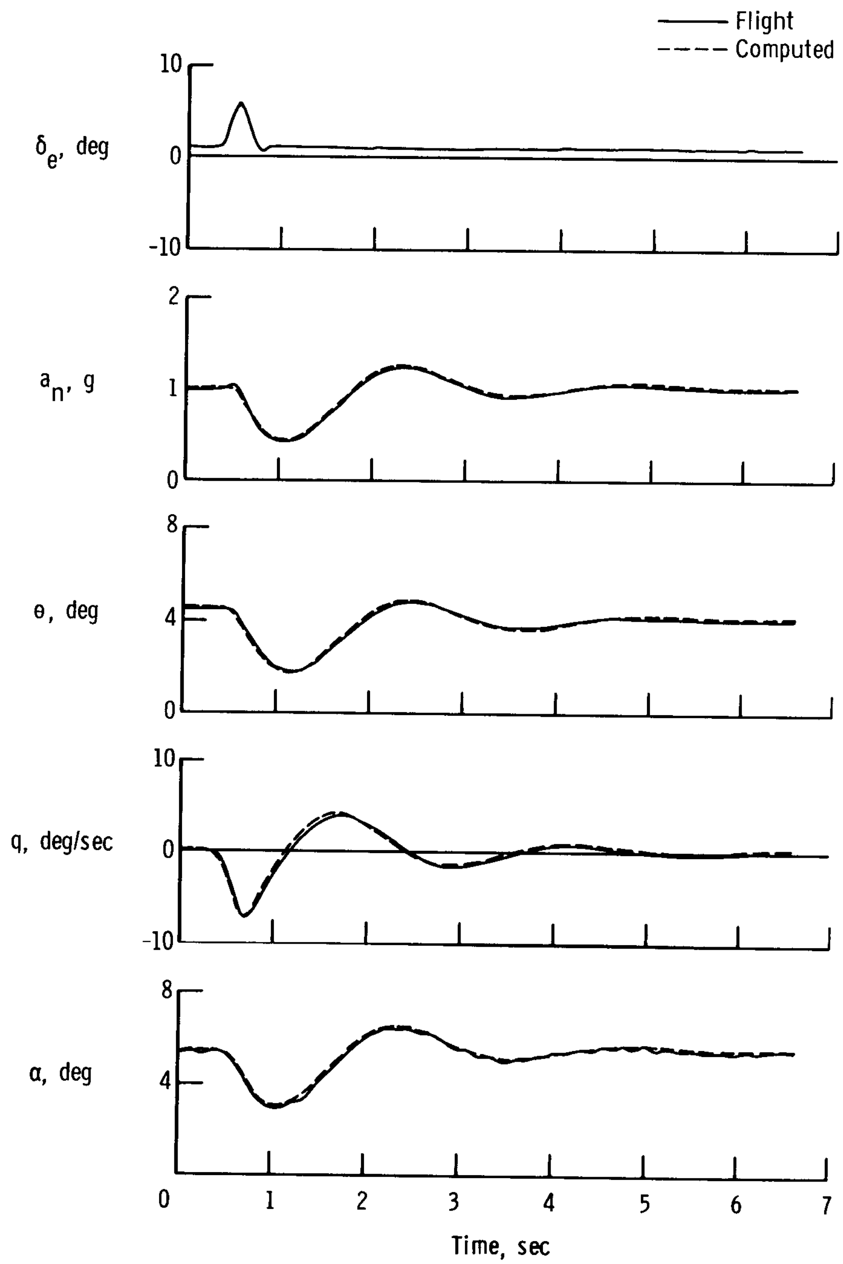
(e) Aircraft E; δ_a and δ_r pulse.

Figure 1. Concluded.



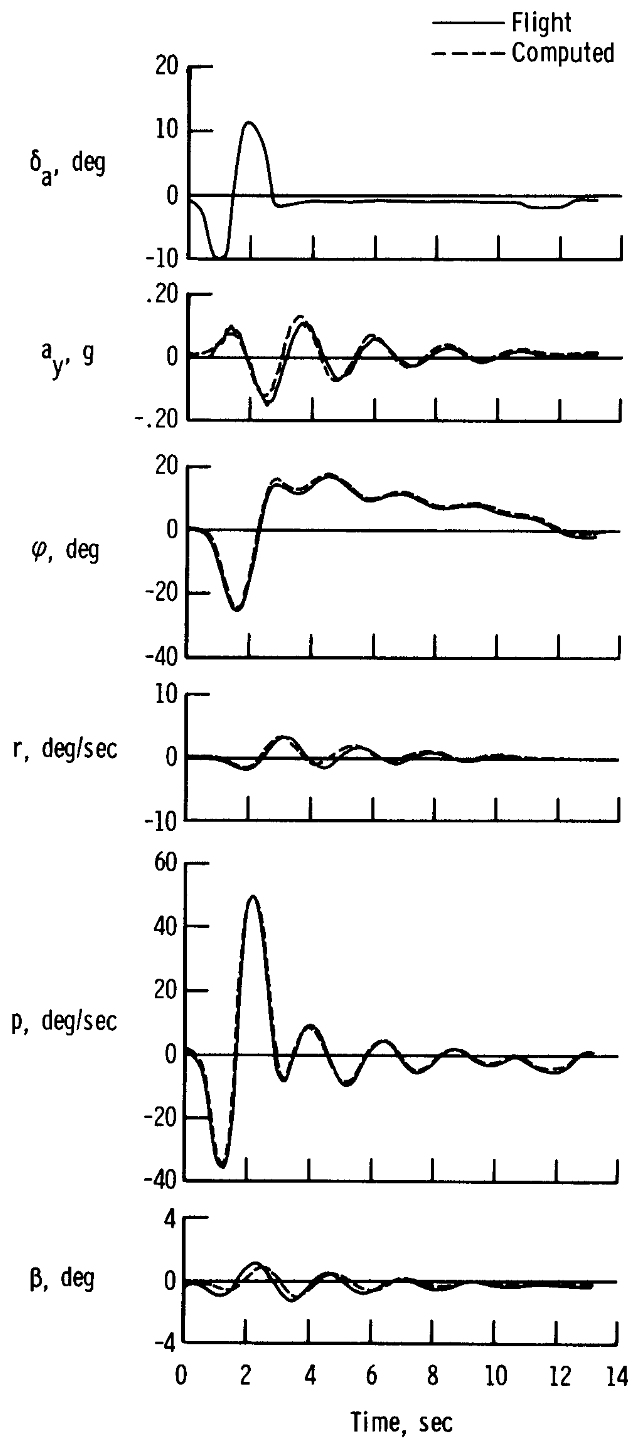
(a) Aircraft B.

Figure 2. Typical match between computed and flight time histories for longitudinal maneuvers with no time shift. δ_e pulses.



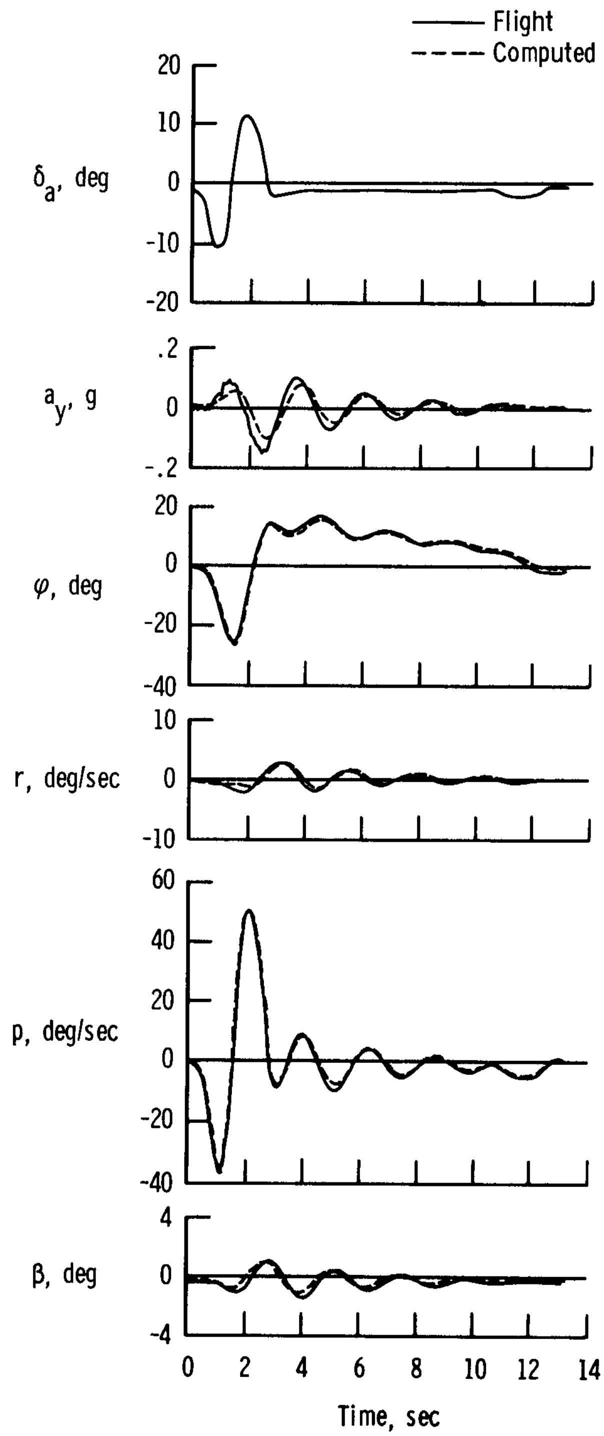
(b) Aircraft C.

Figure 2. Concluded.



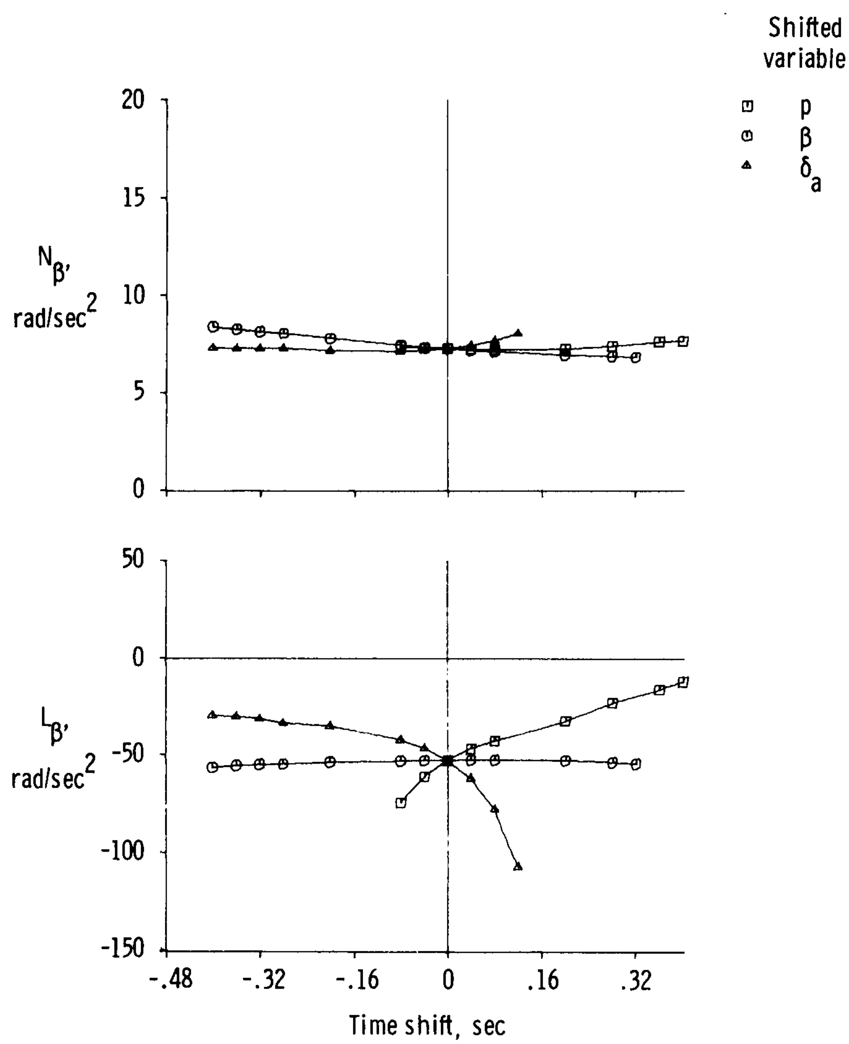
(a) Shift = −8 time increments (−0.32 second).

Figure 3. Matches between computed and flight time histories with time shifts in β of −8 and +8 time increments. Aircraft A.



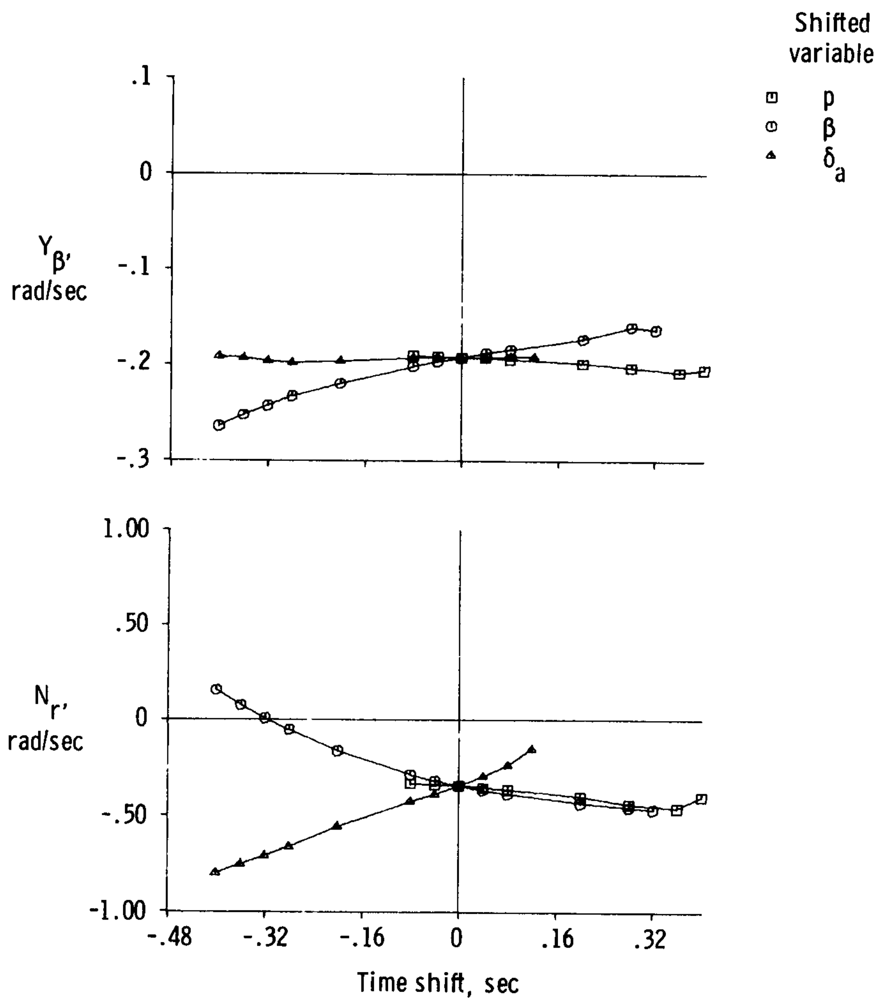
(b) Shift = +8 time increments (+0.32 second).

Figure 3. Concluded.



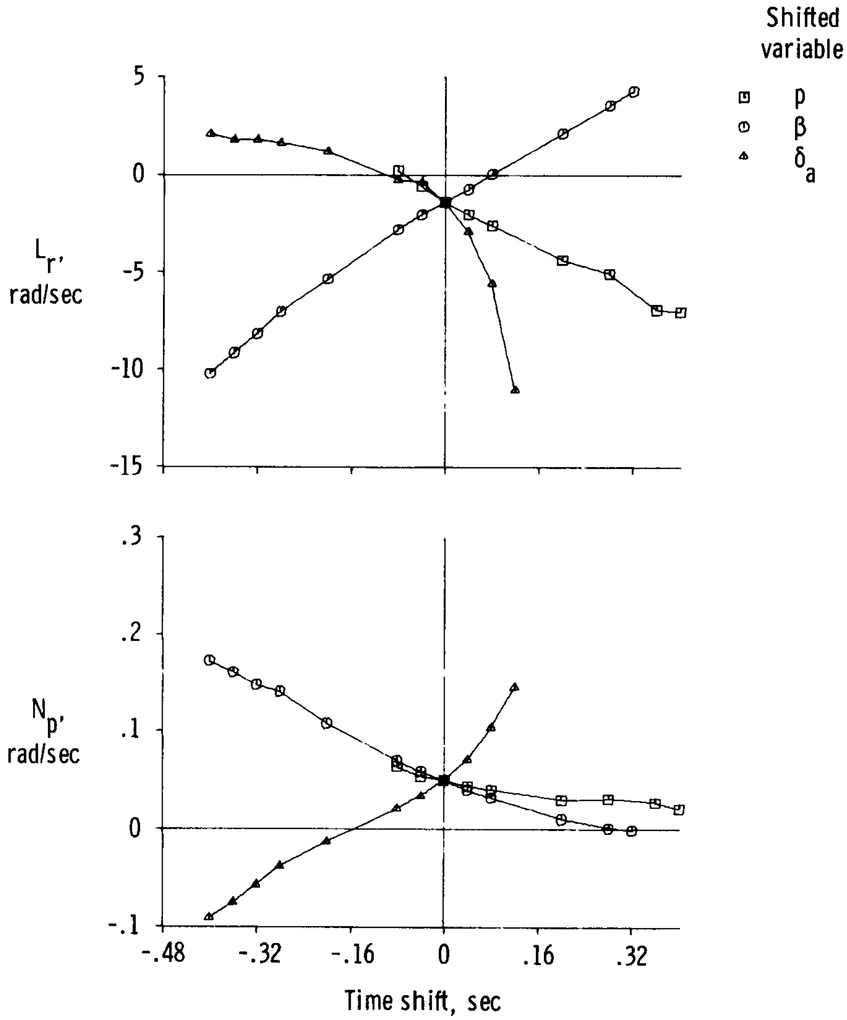
(a)

Figure 4. Estimated lateral-directional derivatives as a function of time-shift increment for a δ_a maneuver. Aircraft A.



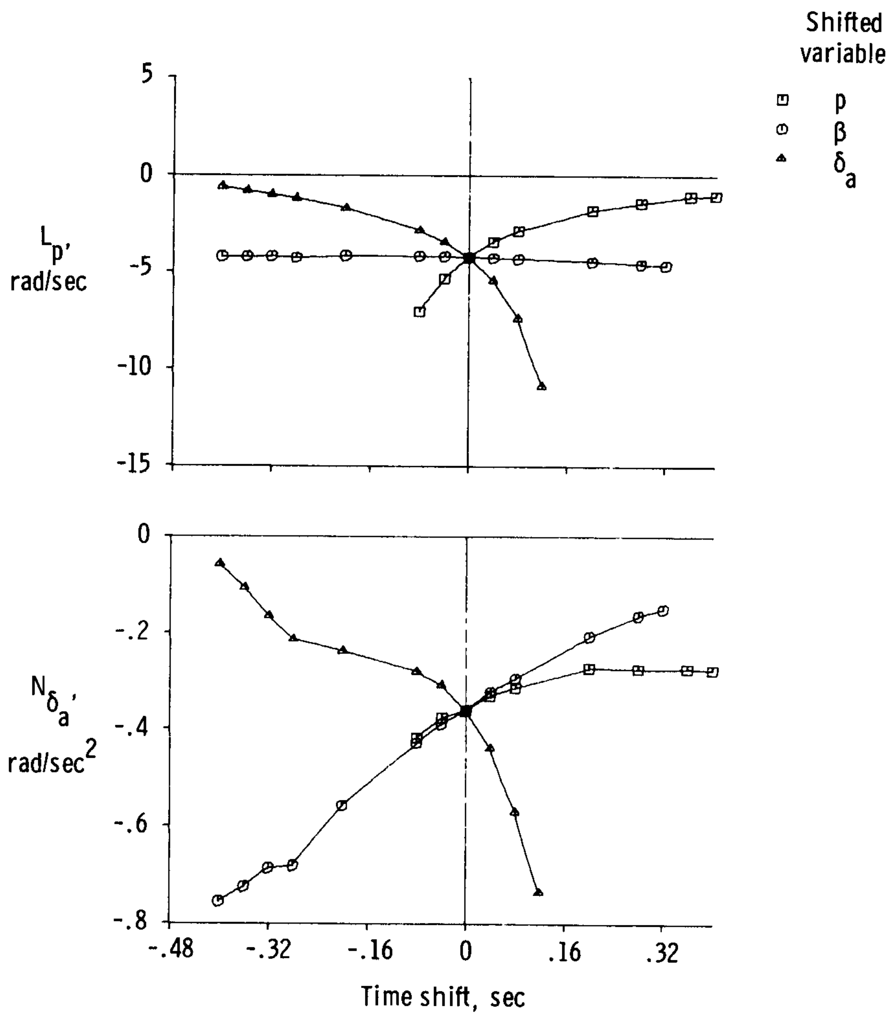
(b)

Figure 4. Continued.



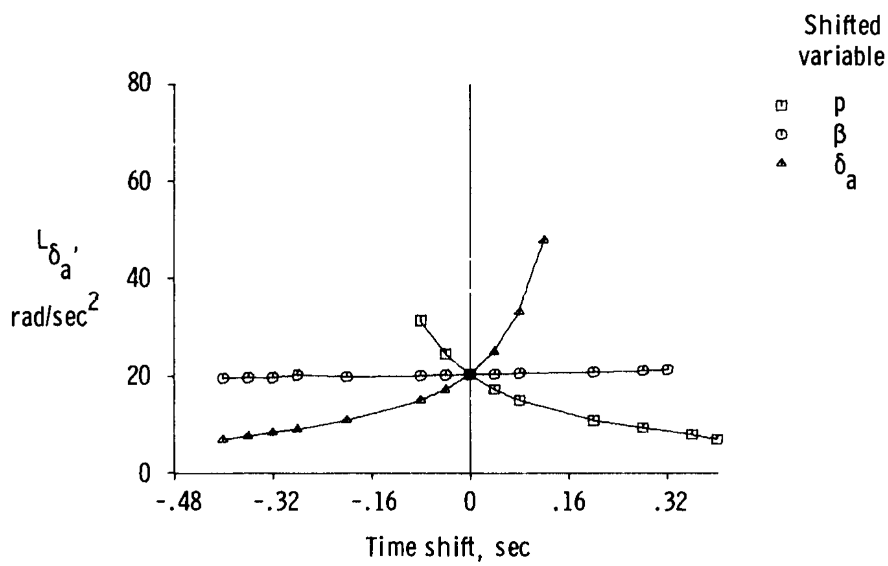
(c)

Figure 4. Continued.



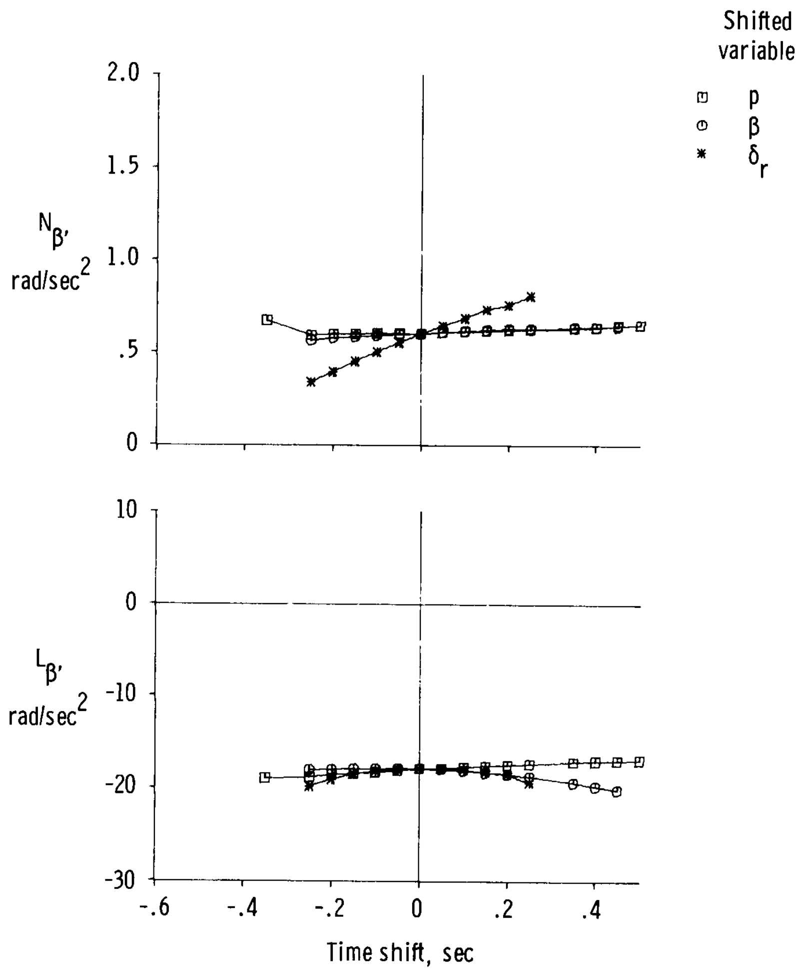
(d)

Figure 4. Continued.



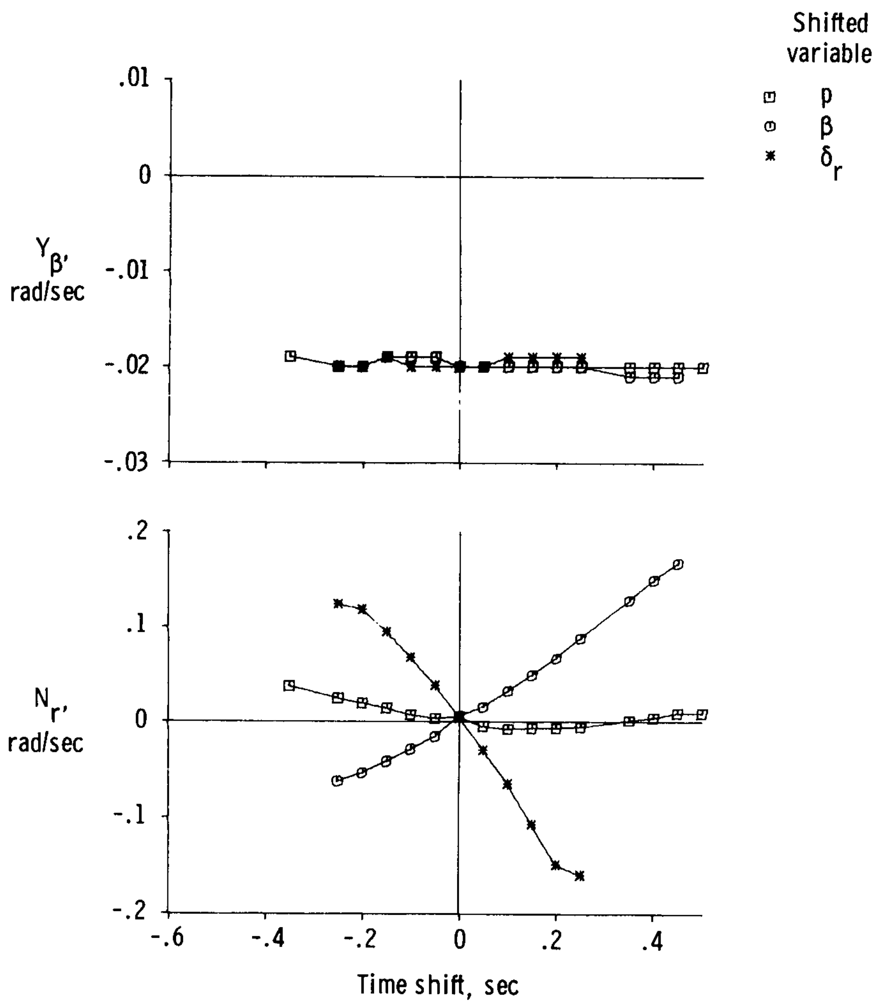
(e)

Figure 4. Concluded.



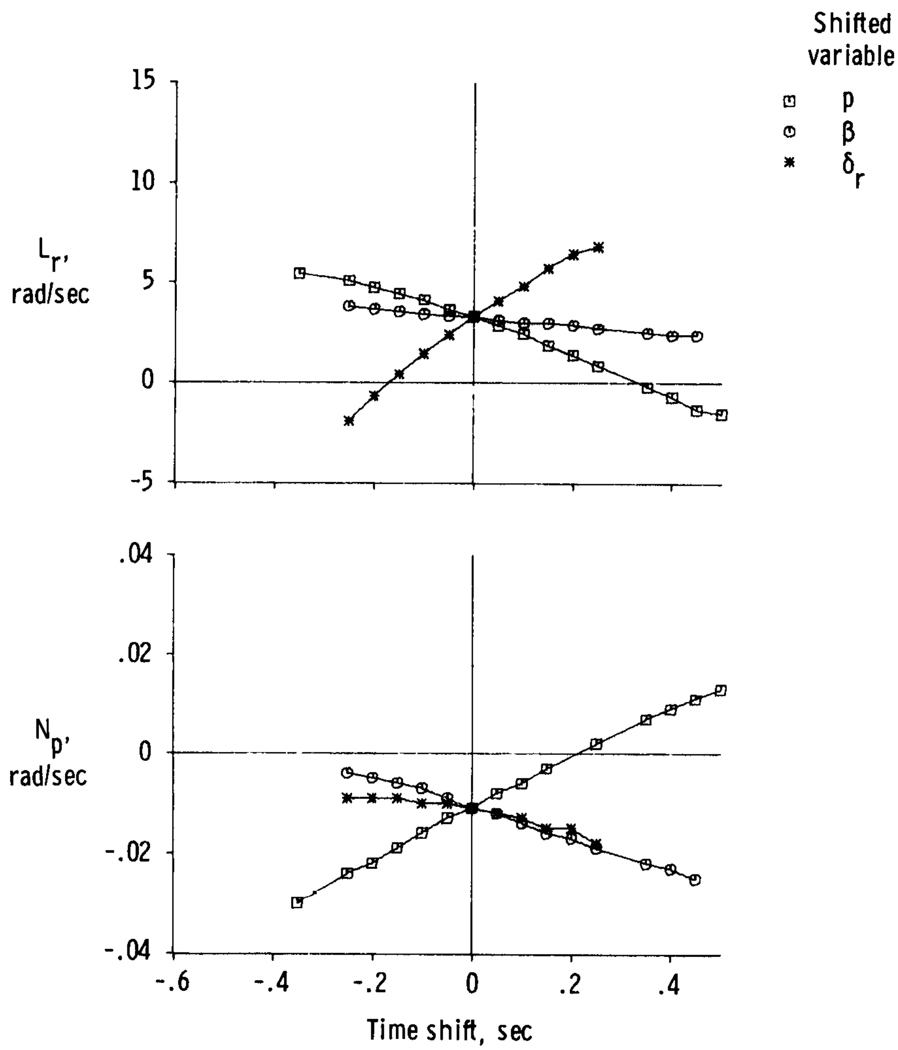
(a)

Figure 5. Estimated lateral-directional derivatives as a function of time-shift increment for a δ_r maneuver. Aircraft B.



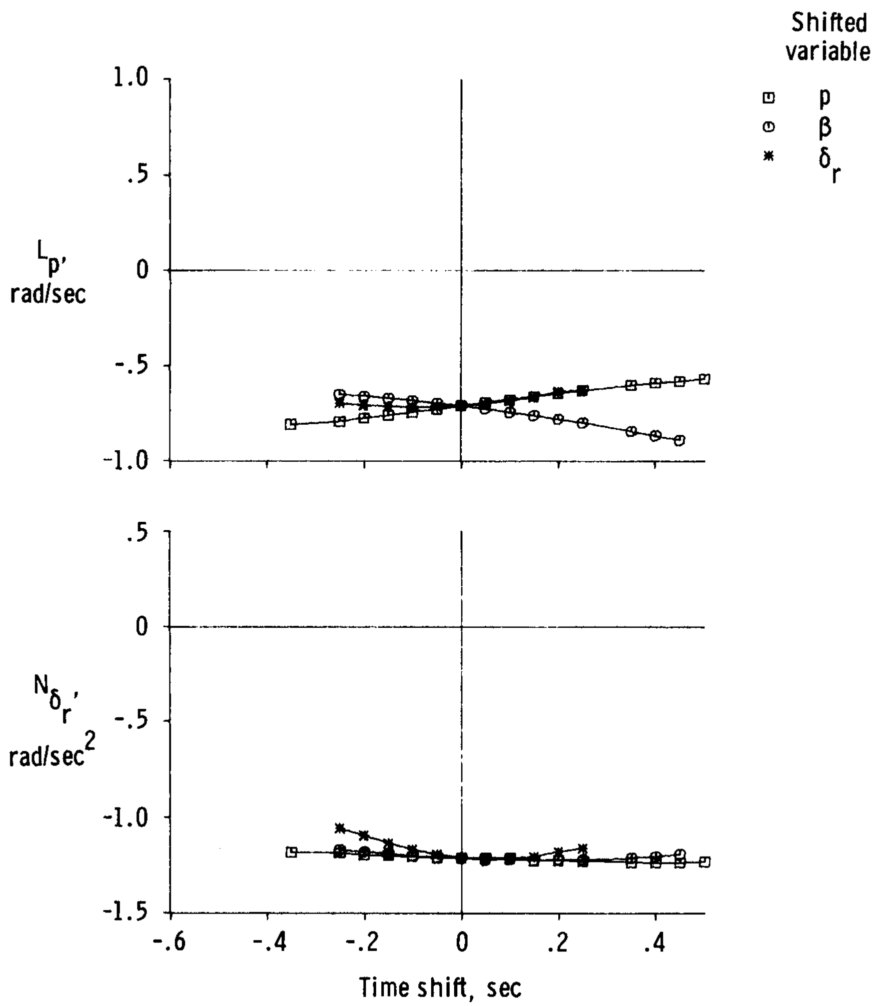
(b)

Figure 5. Continued.



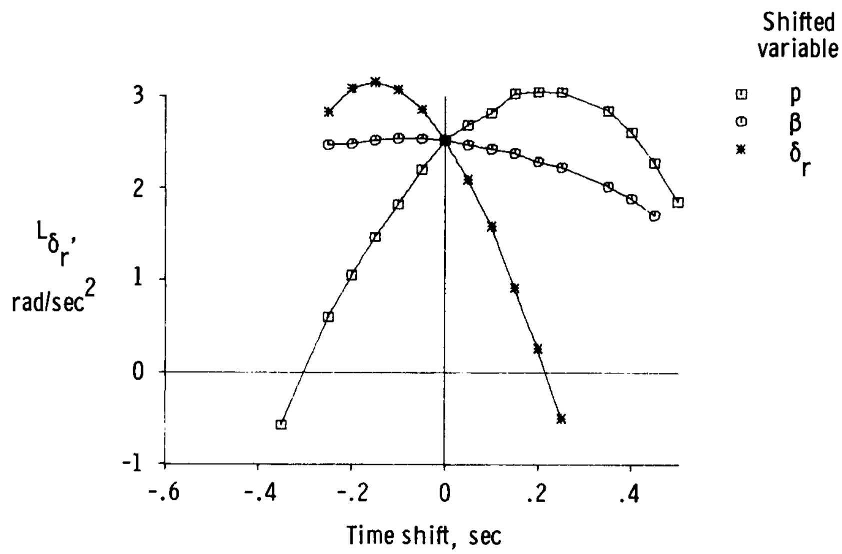
(c)

Figure 5. Continued.



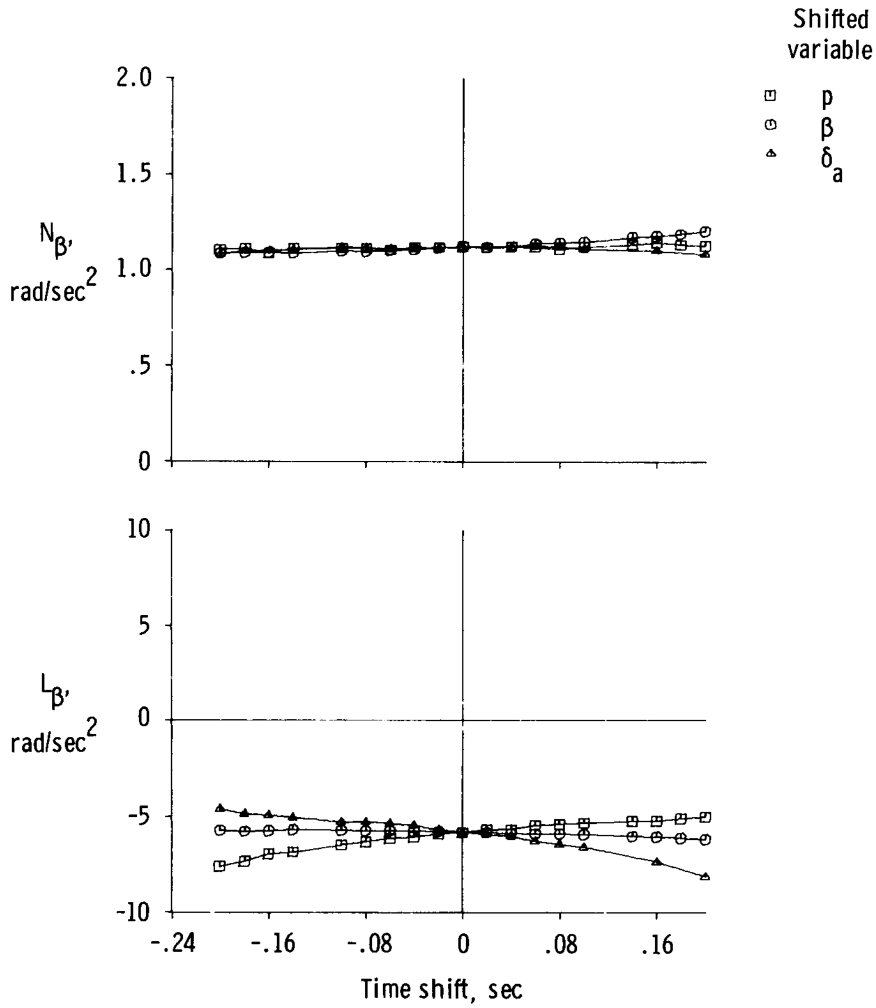
(d)

Figure 5. Continued.



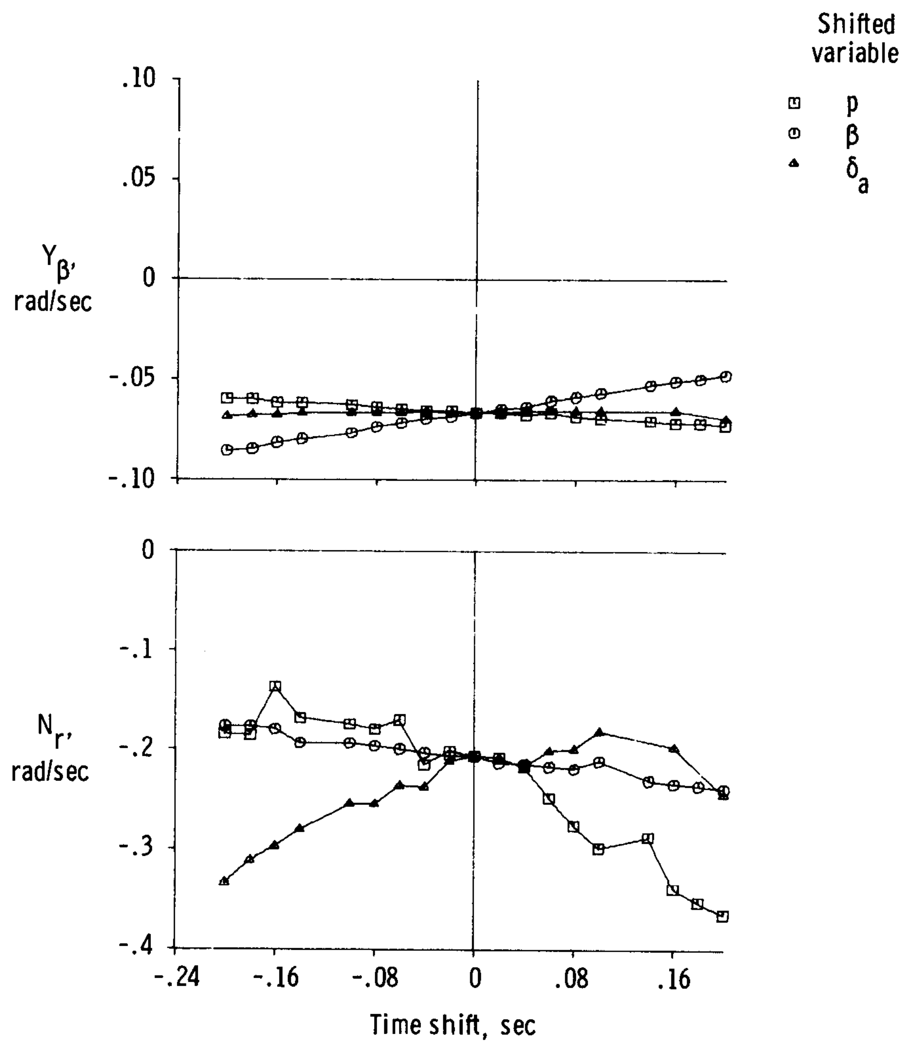
(e)

Figure 5. Concluded.



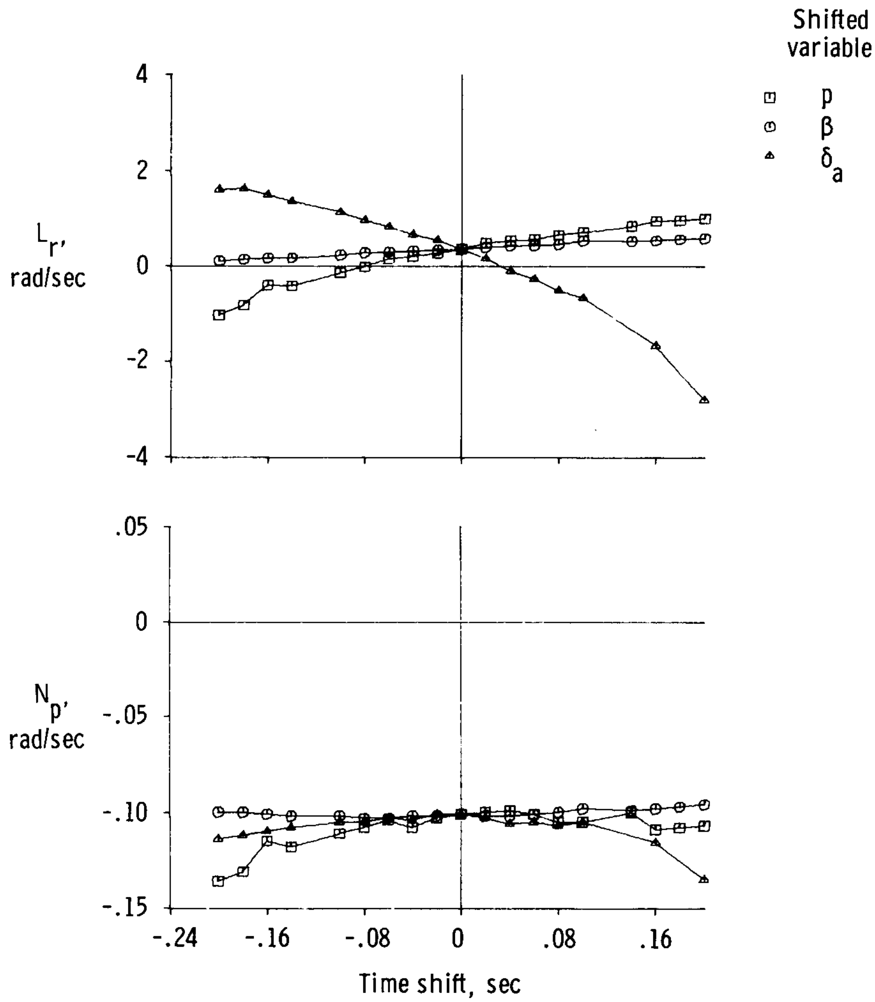
(a)

Figure 6. Estimated lateral-directional derivatives as a function of time-shift increment for a δ_a maneuver. Aircraft C.



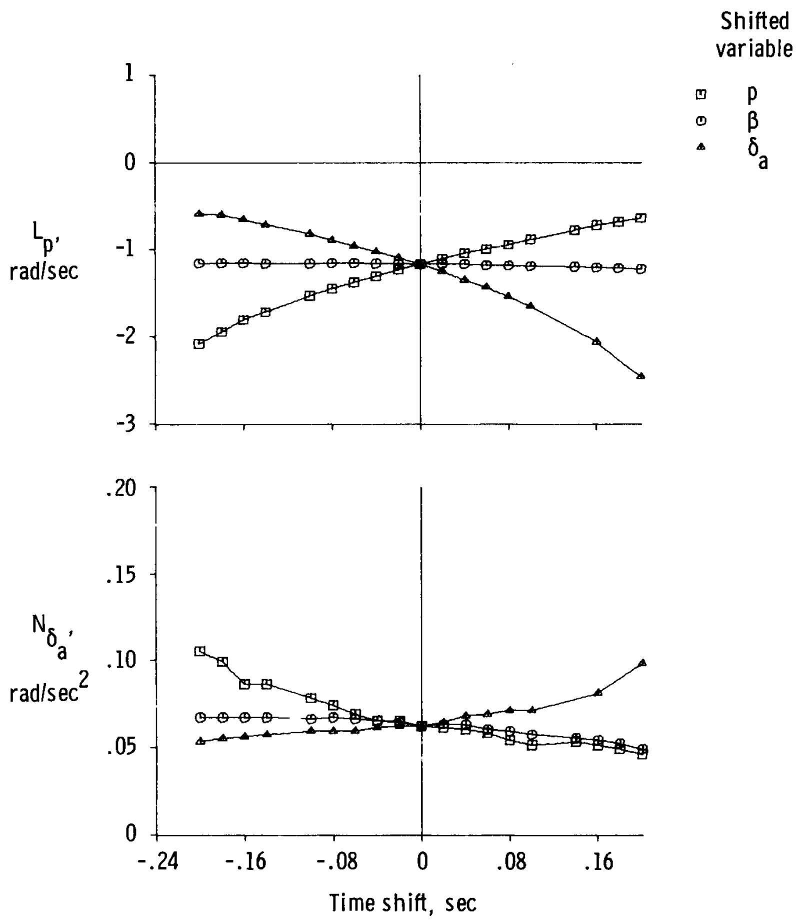
(b)

Figure 6. Continued.



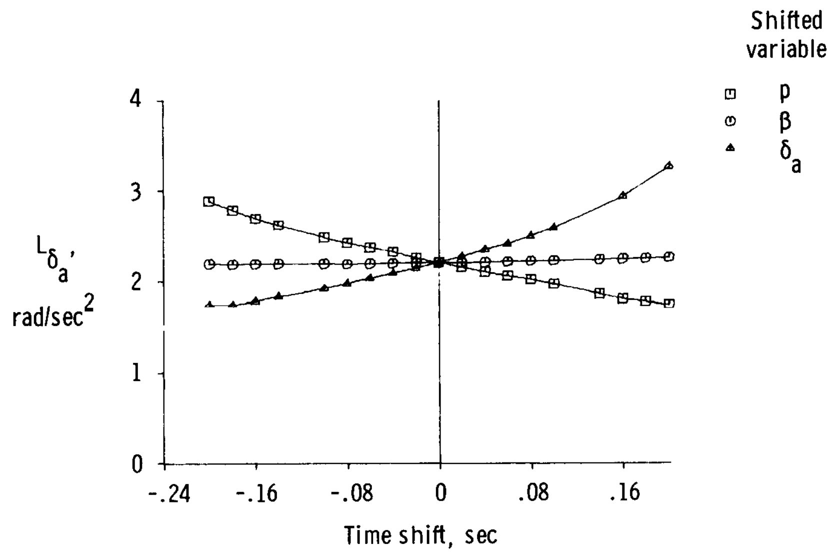
(c)

Figure 6. Continued.



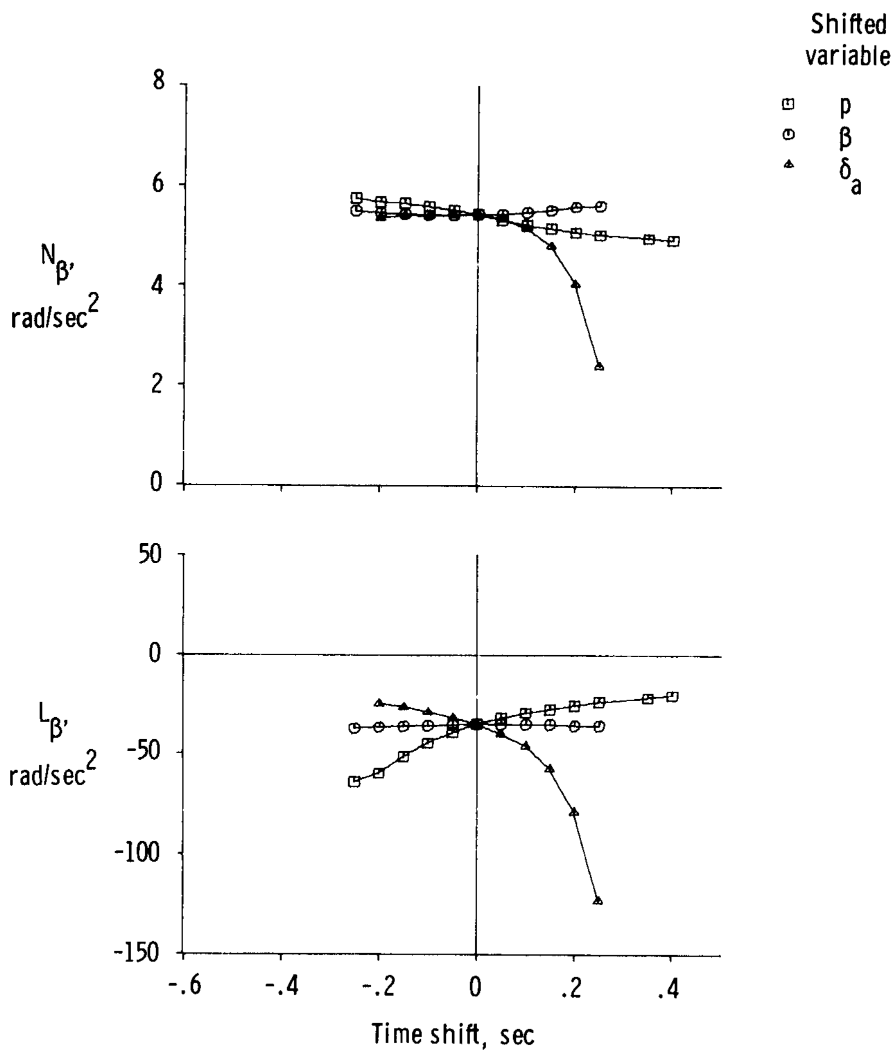
(d)

Figure 6. Continued.



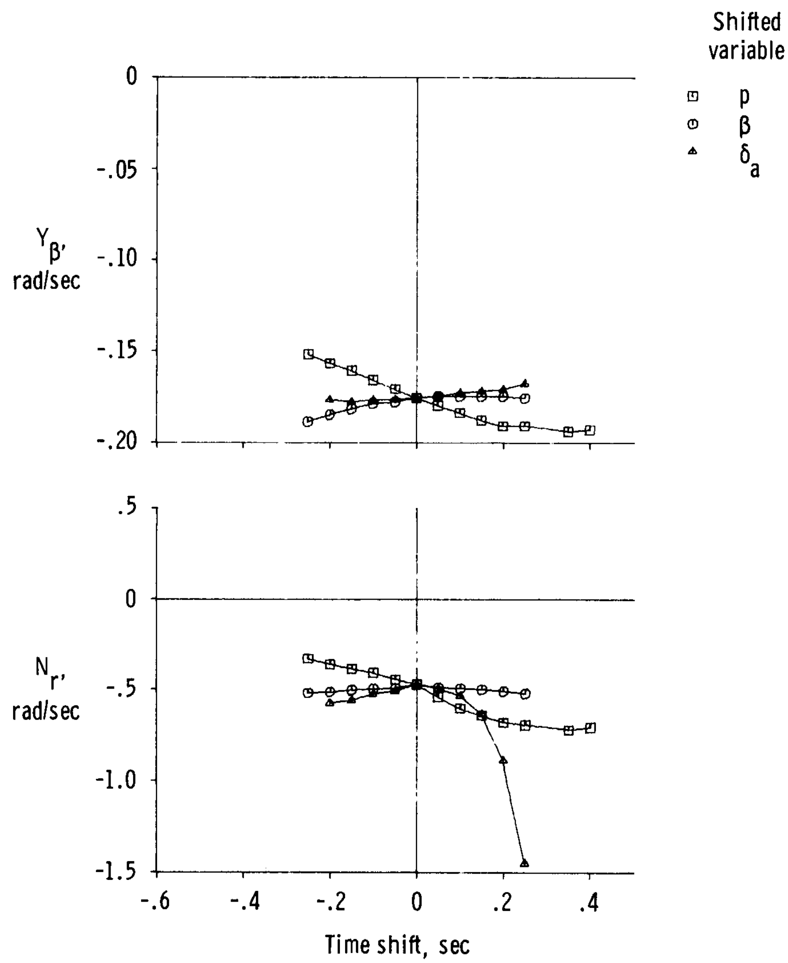
(e)

Figure 6. Concluded.



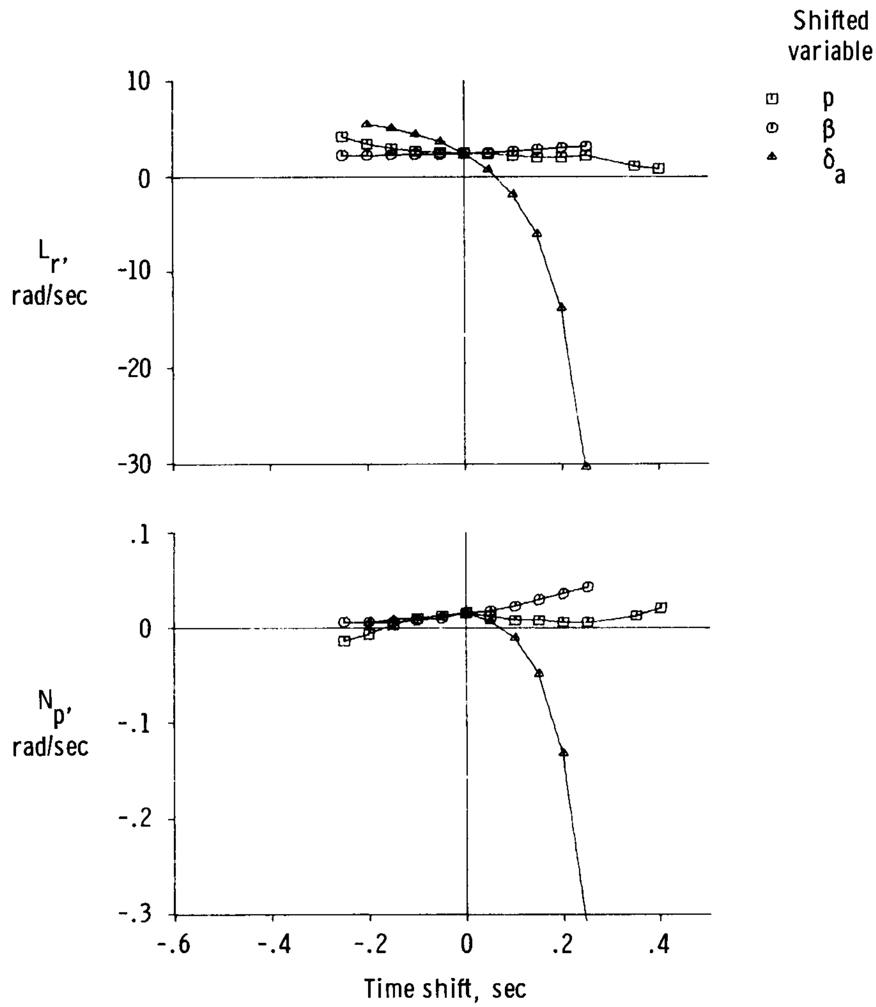
(a)

Figure 7. Estimated lateral-directional derivatives as a function of time-shift increment for a δ_a and δ_r maneuver. Aircraft D.



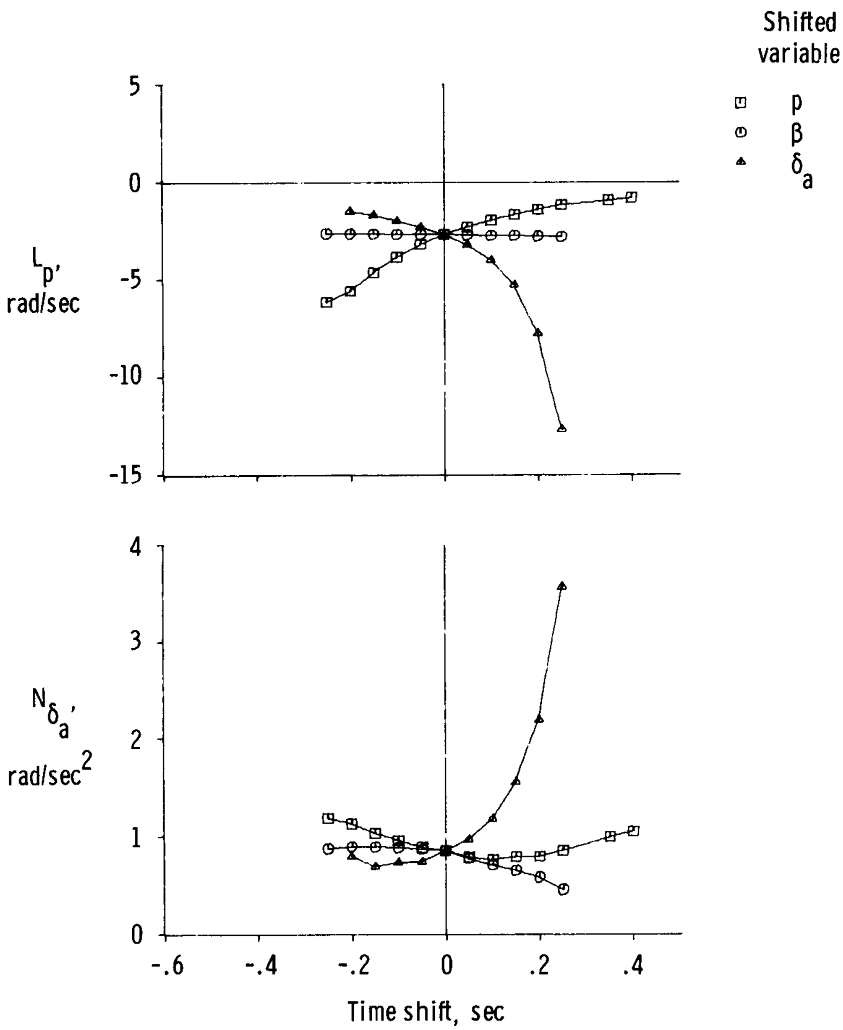
(b)

Figure 7. Continued.



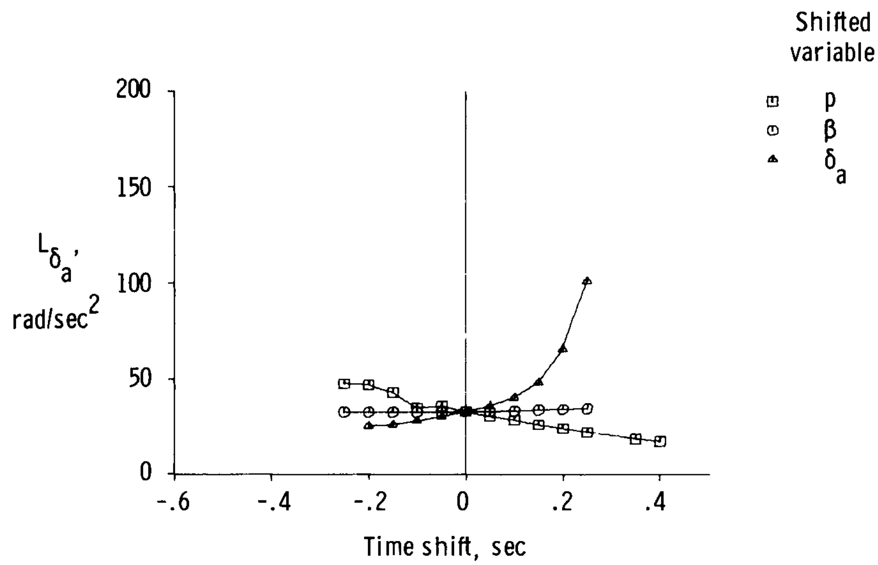
(c)

Figure 7. Continued.



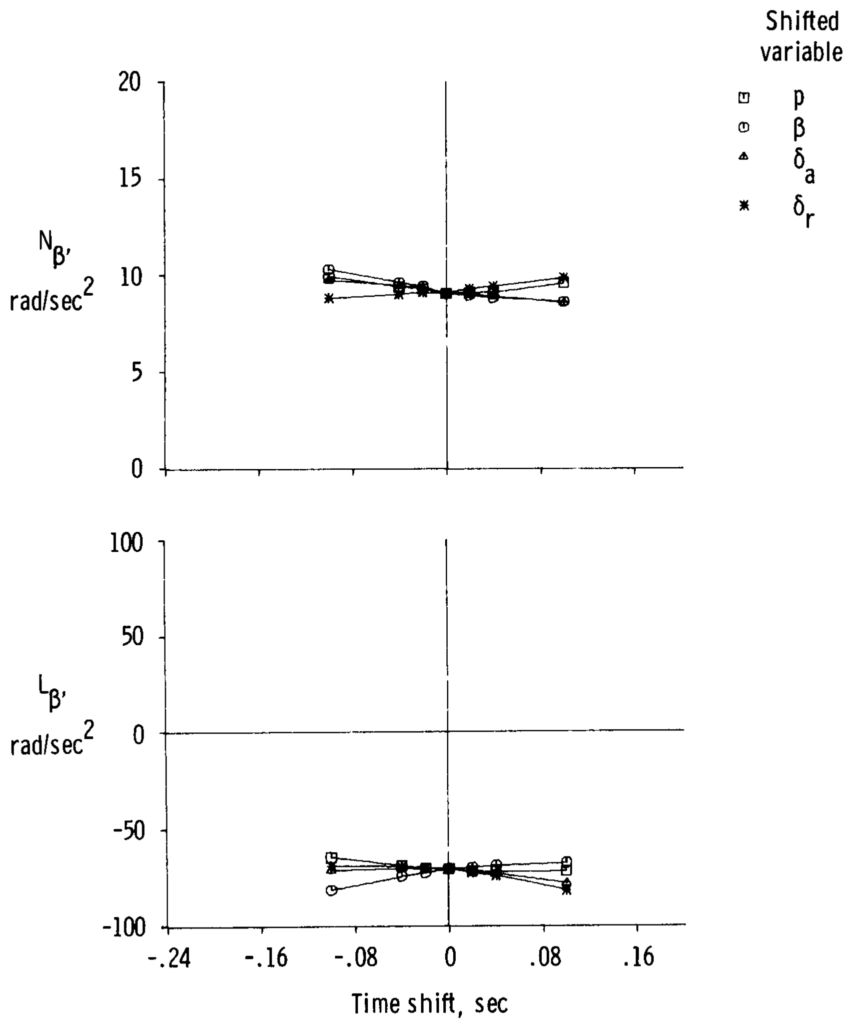
(d)

Figure 7. Continued.



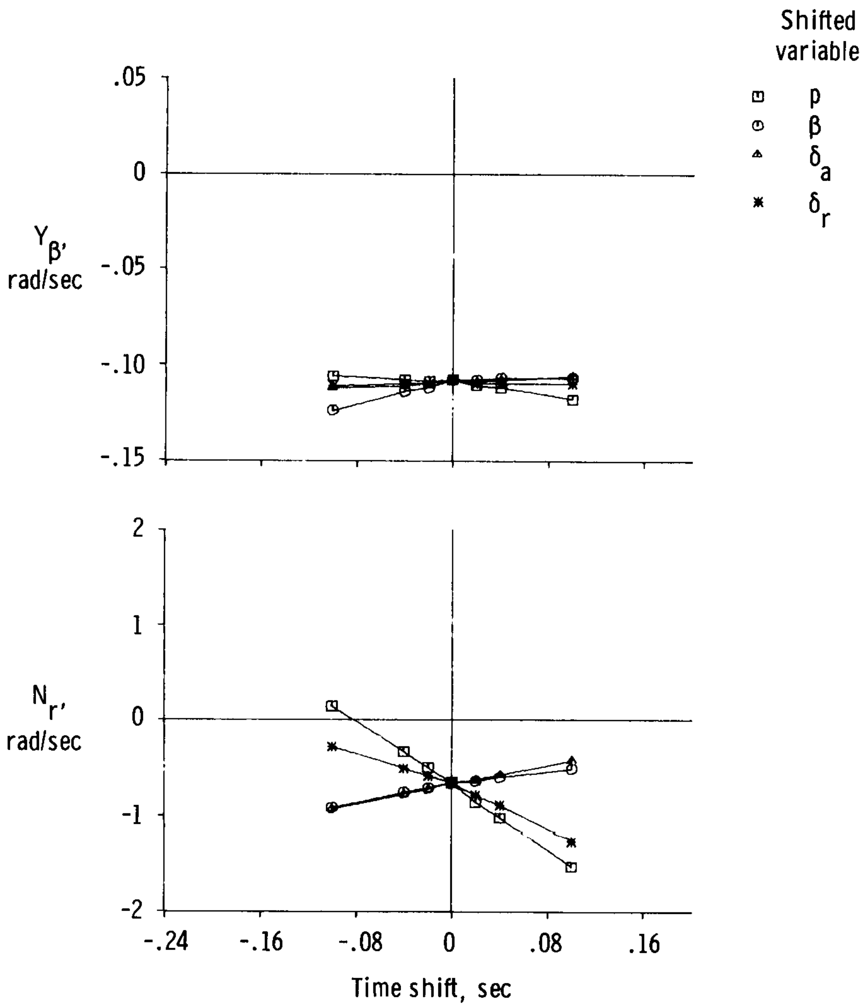
(e)

Figure 7. Concluded.



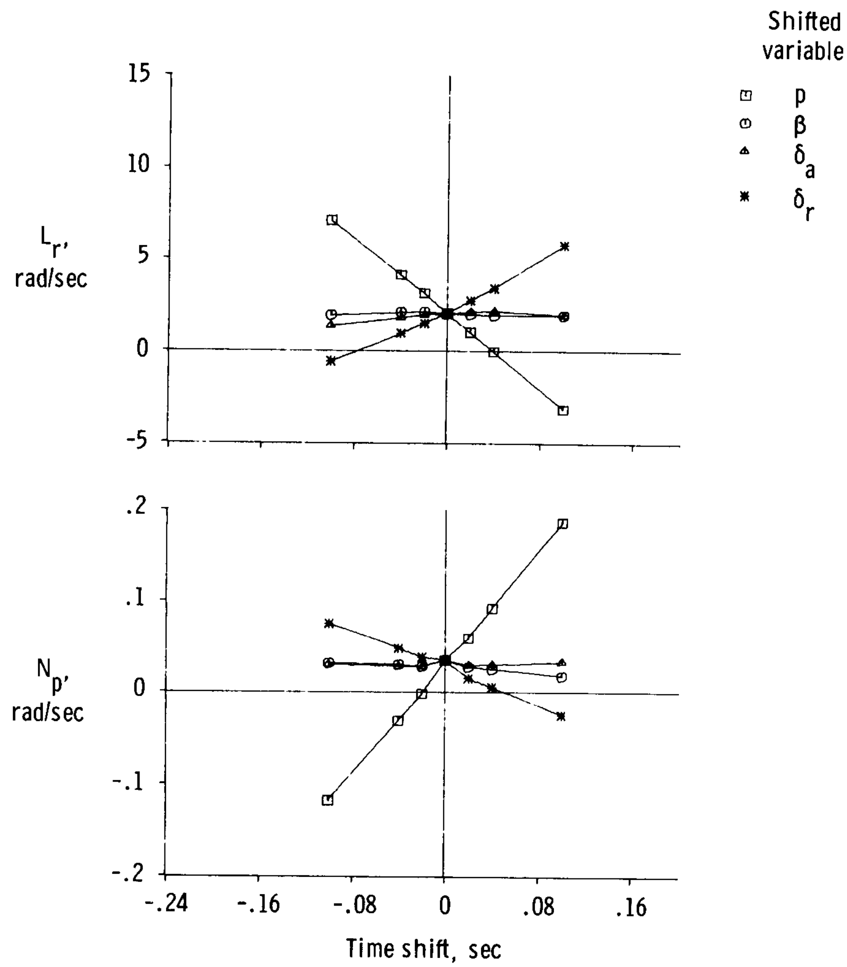
(a)

Figure 8. Estimated lateral-directional derivatives as a function of time-shift increment for a δ_a and δ_r maneuver. Aircraft E.



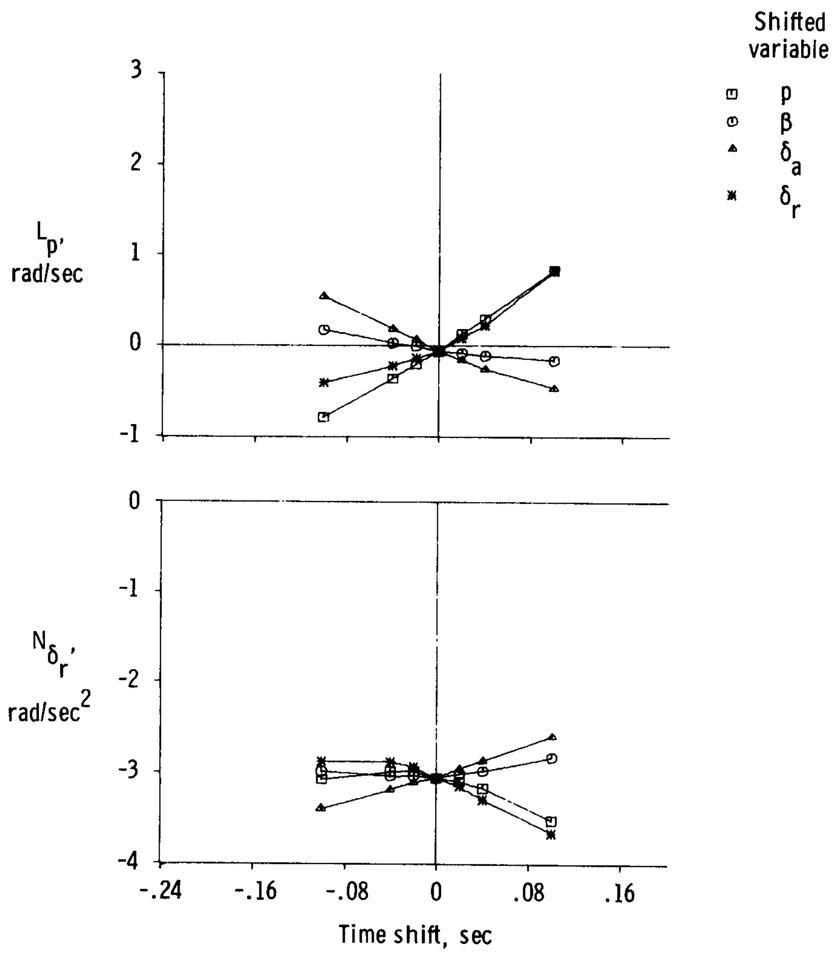
(b)

Figure 8. Continued.



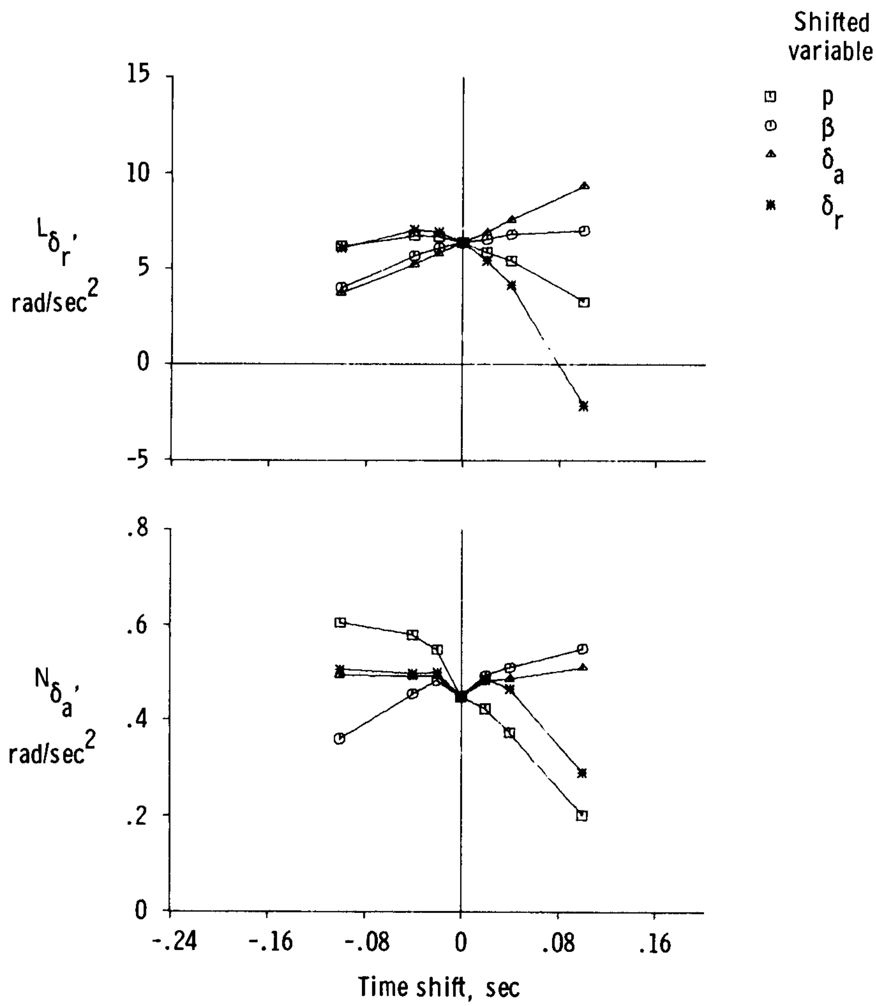
(c)

Figure 8. Continued.



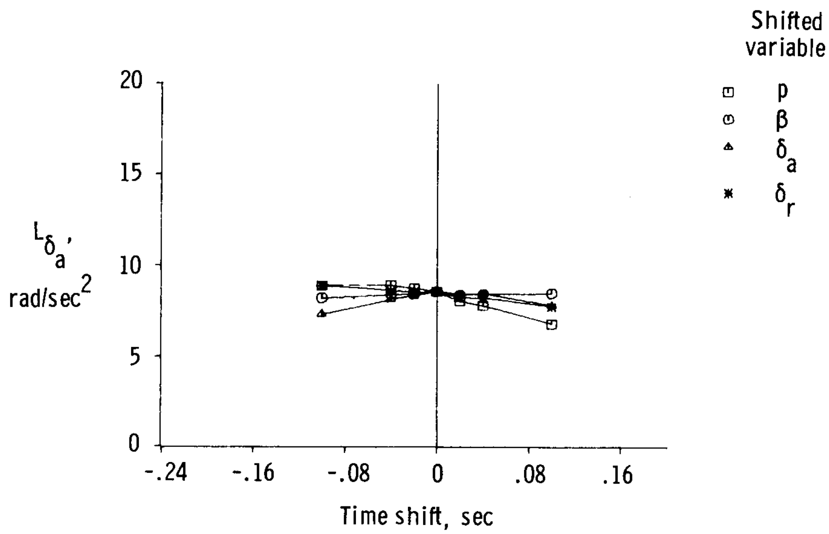
(d)

Figure 8. Continued.



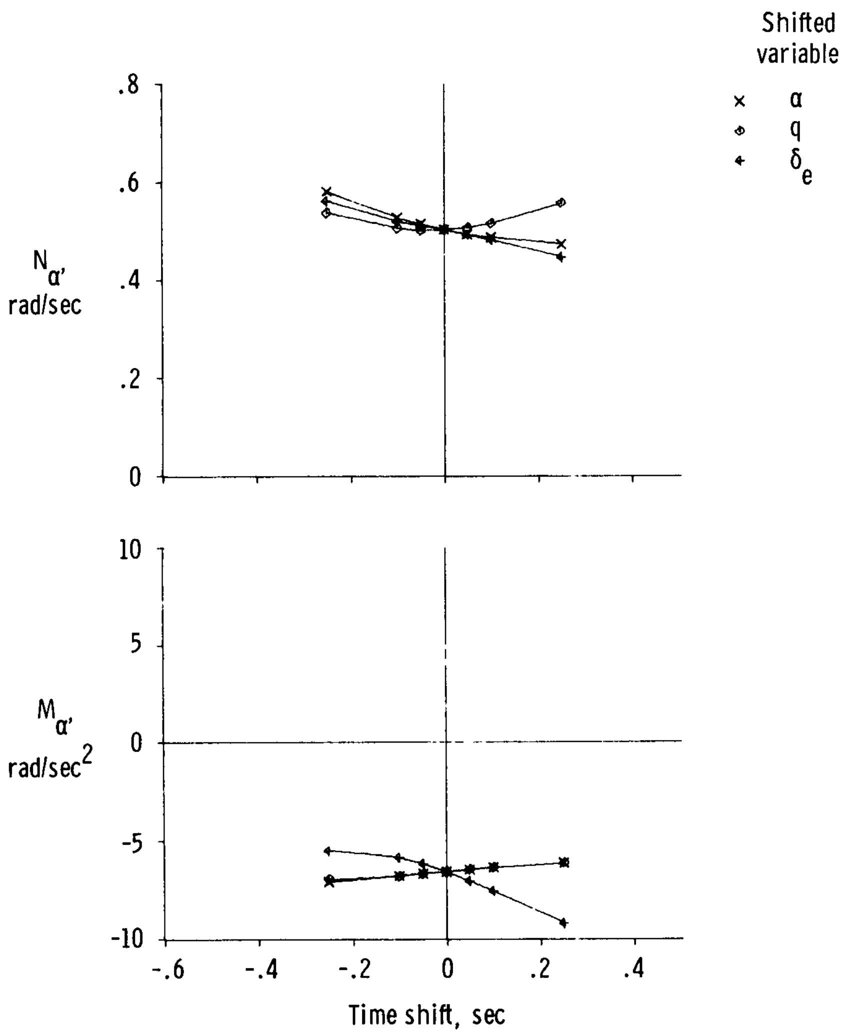
(e)

Figure 8. Continued.



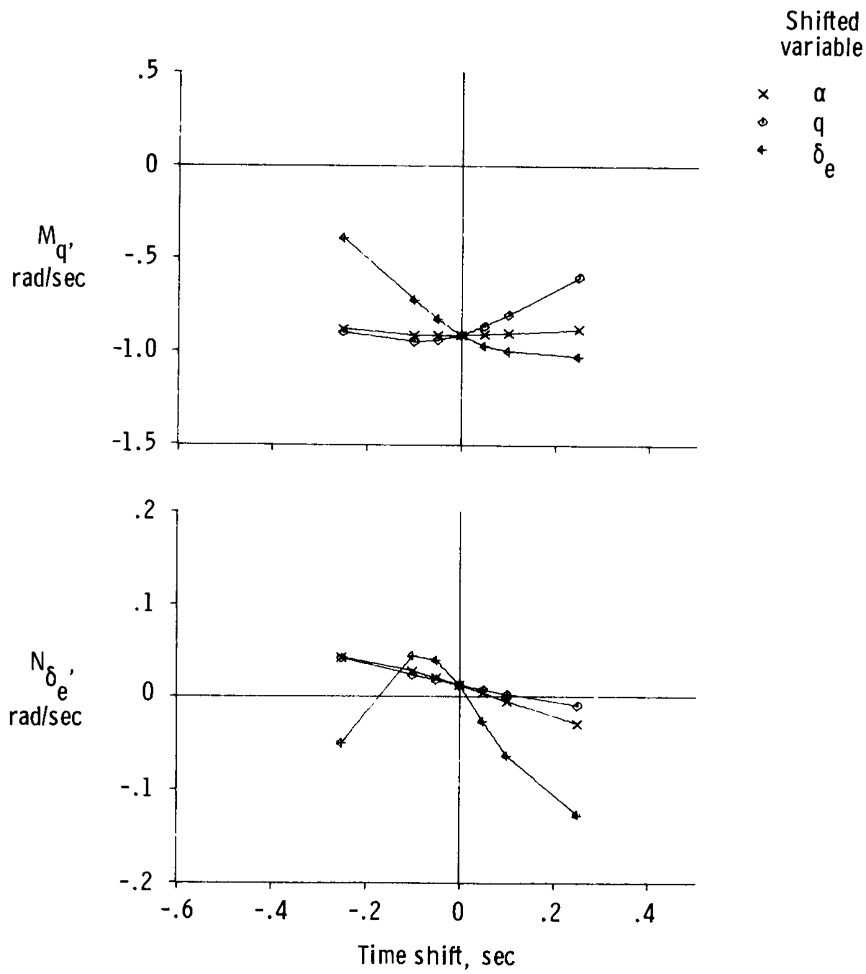
(f)

Figure 8. Concluded.



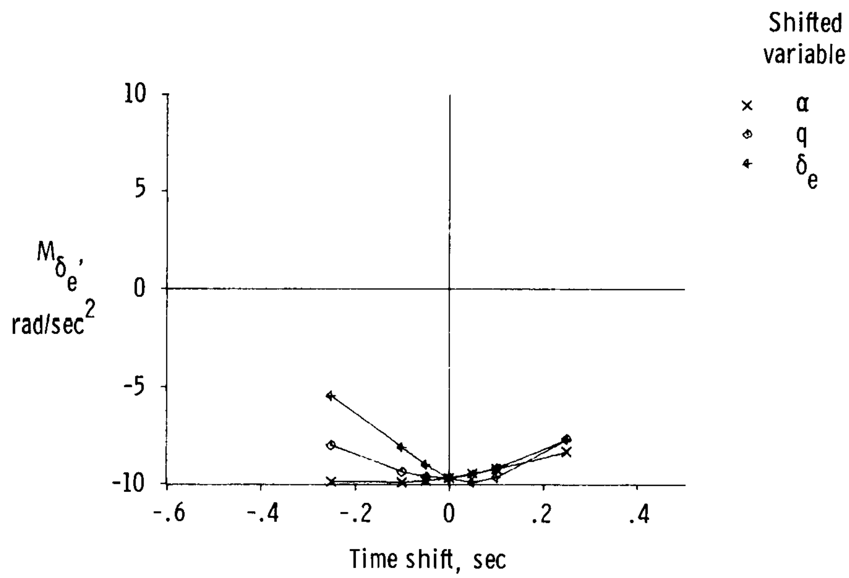
(a)

Figure 9. Estimated longitudinal derivatives as a function of time-shift increment for a δ_e maneuver. Aircraft B.



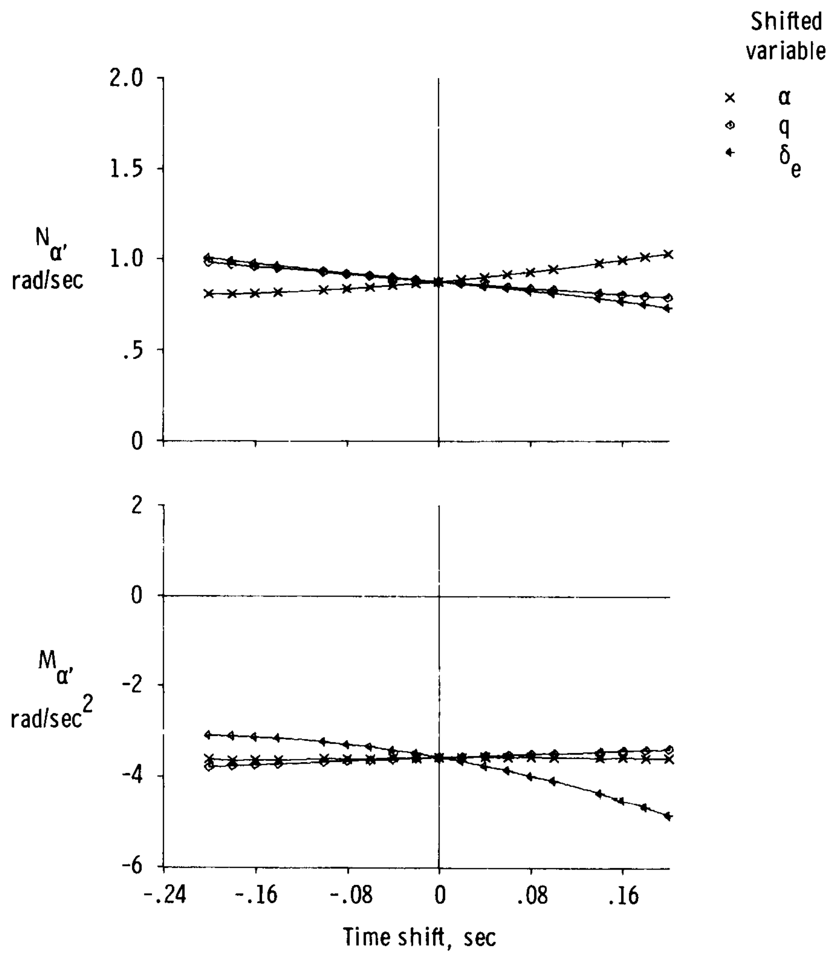
(b)

Figure 9. Continued.



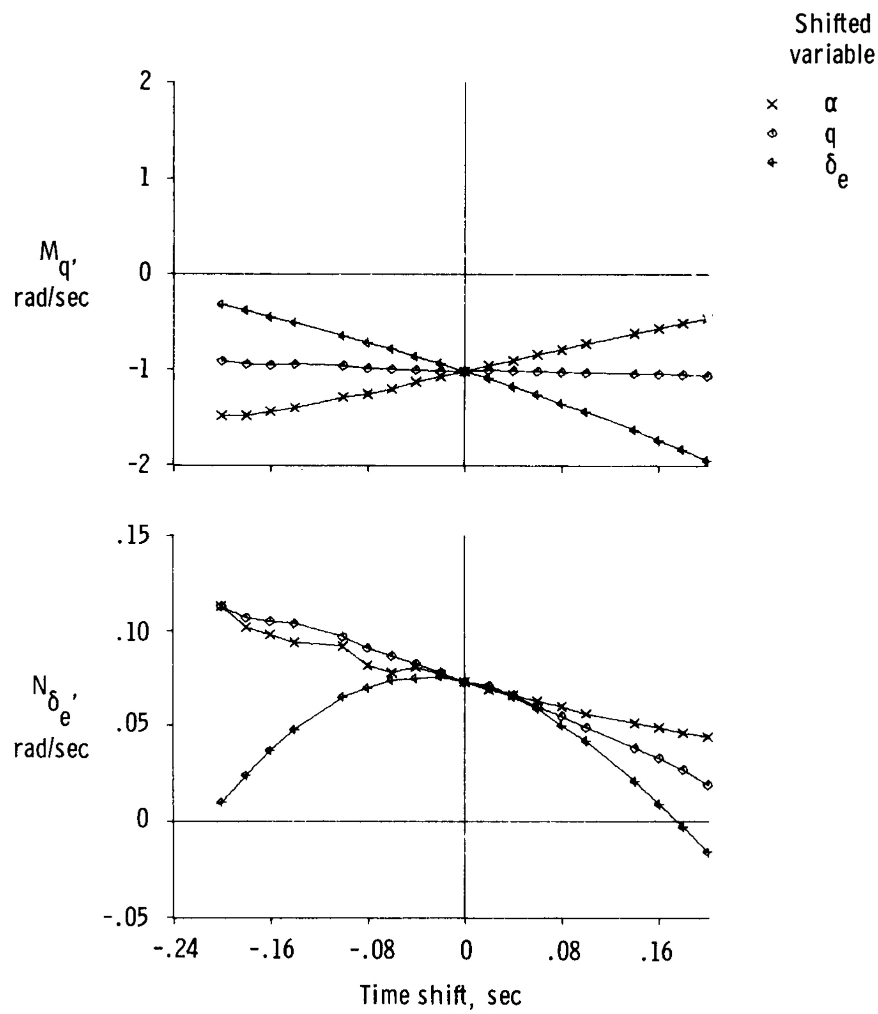
(c)

Figure 9. Concluded.



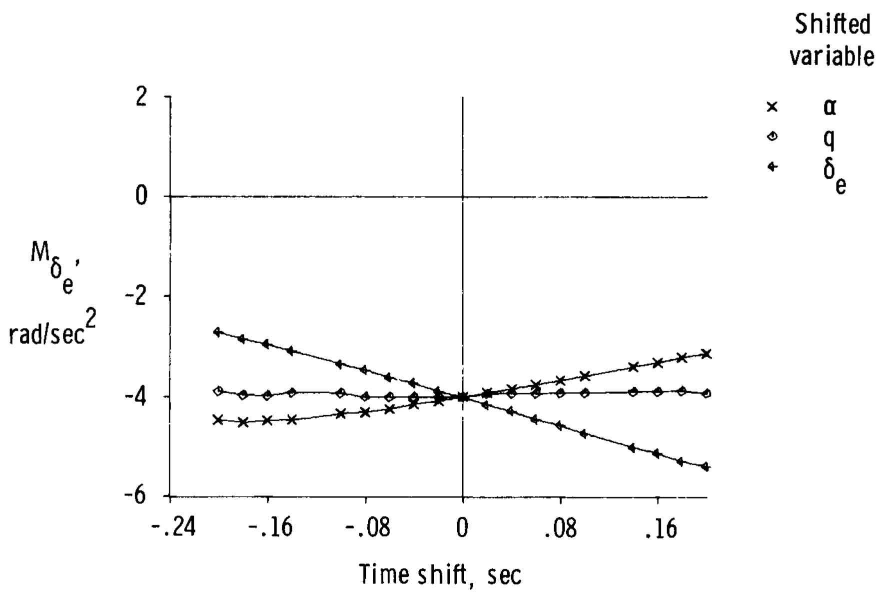
(a)

Figure 10. Estimated longitudinal derivatives as a function of time-shift increment for a δ_e maneuver. Aircraft C.



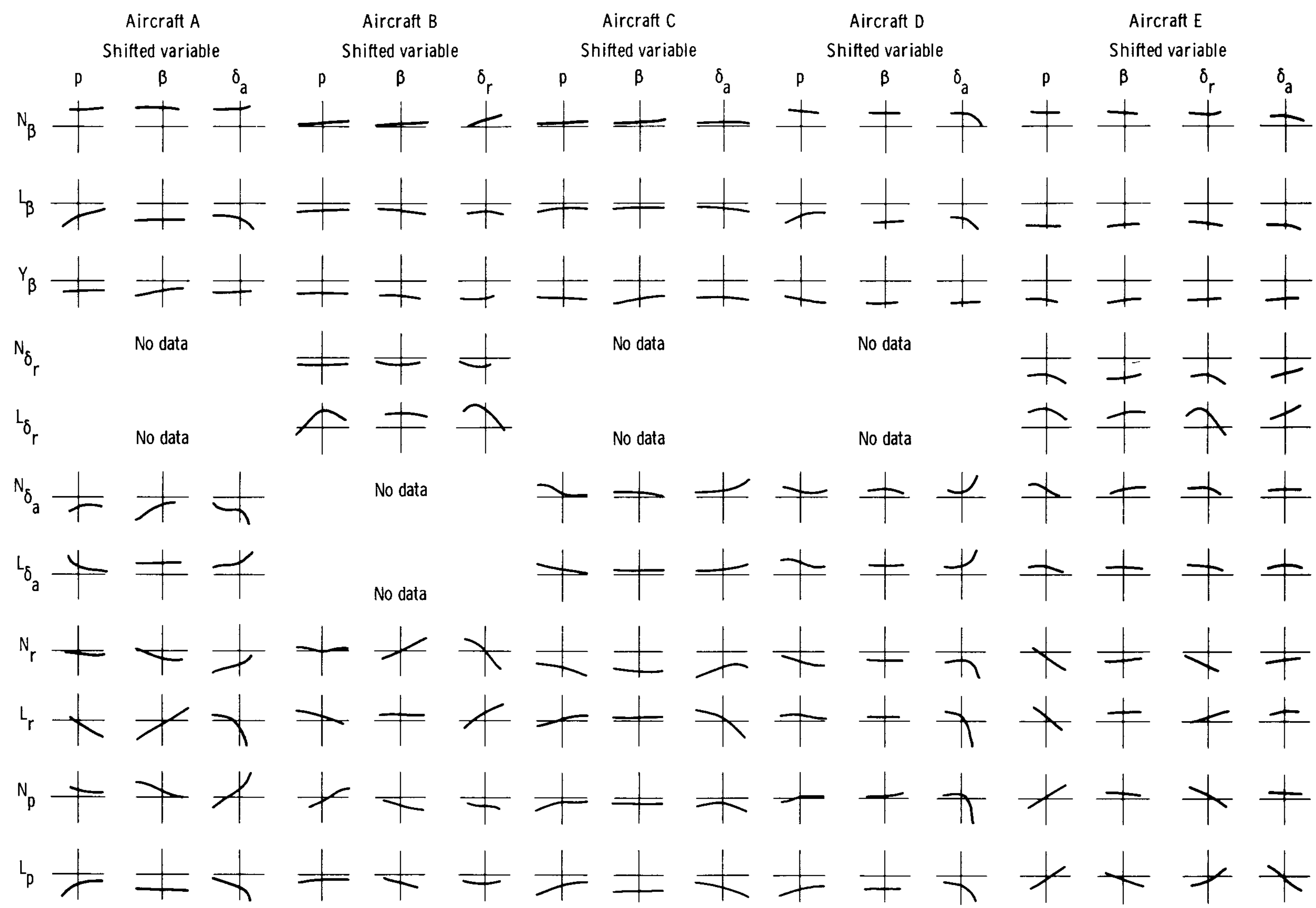
(b)

Figure 10. Continued.



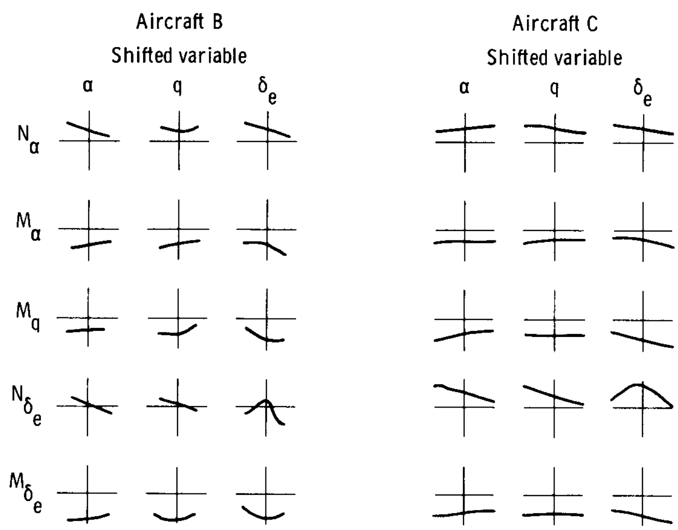
(c)

Figure 10. Concluded.



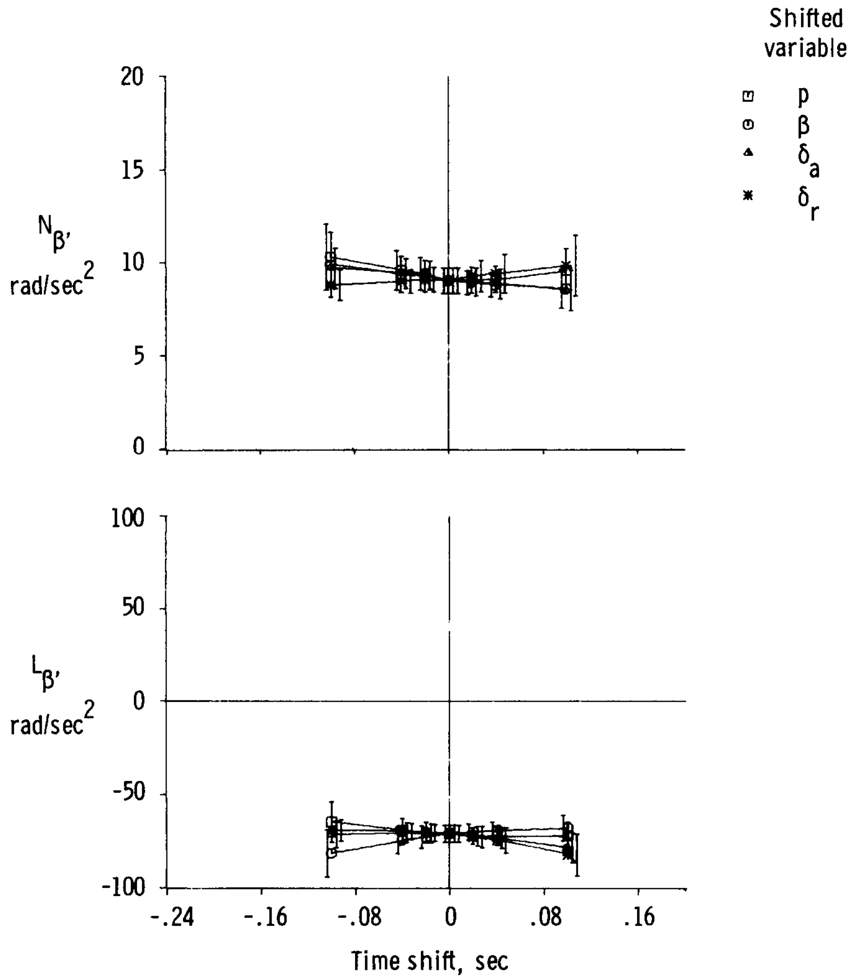
(a) *Lateral-directional derivatives.*

Figure 11. Trends in derivatives estimated from time-shifted data.



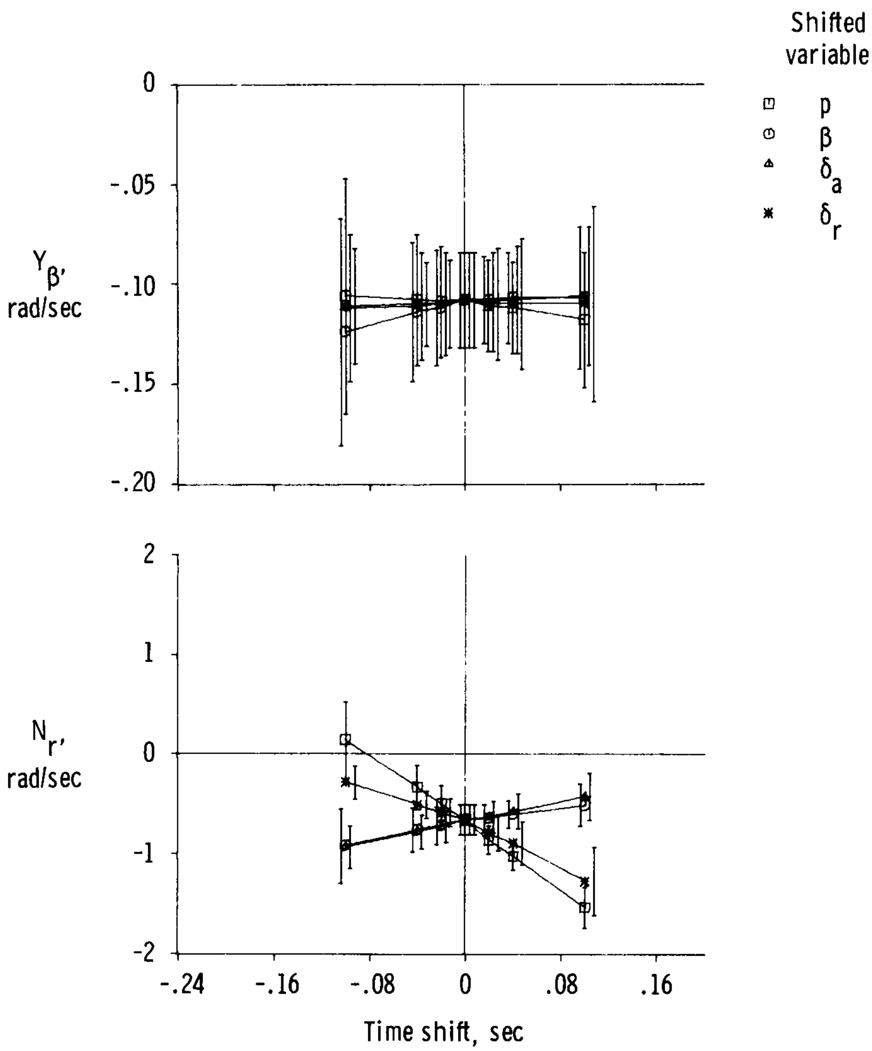
(b) Longitudinal derivatives.

Figure 11. Concluded.



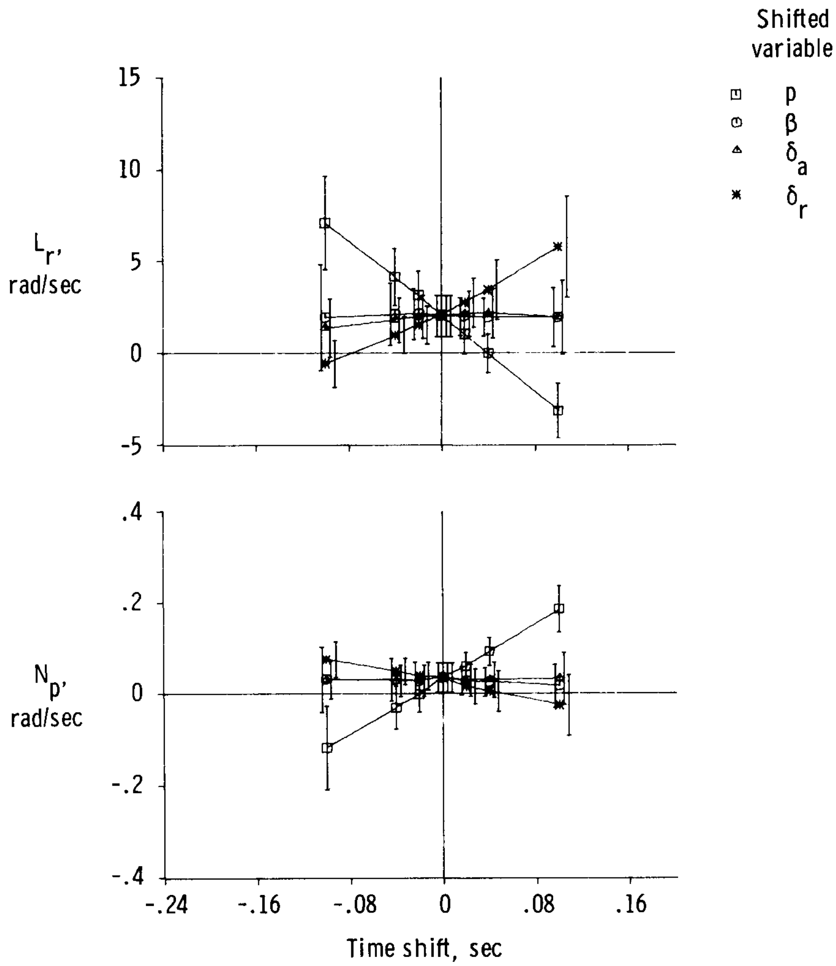
(a)

Figure 12. Estimated lateral-directional derivatives and uncertainty levels as a function of time-shift increment for a δ_a and δ_r maneuver. Aircraft E.



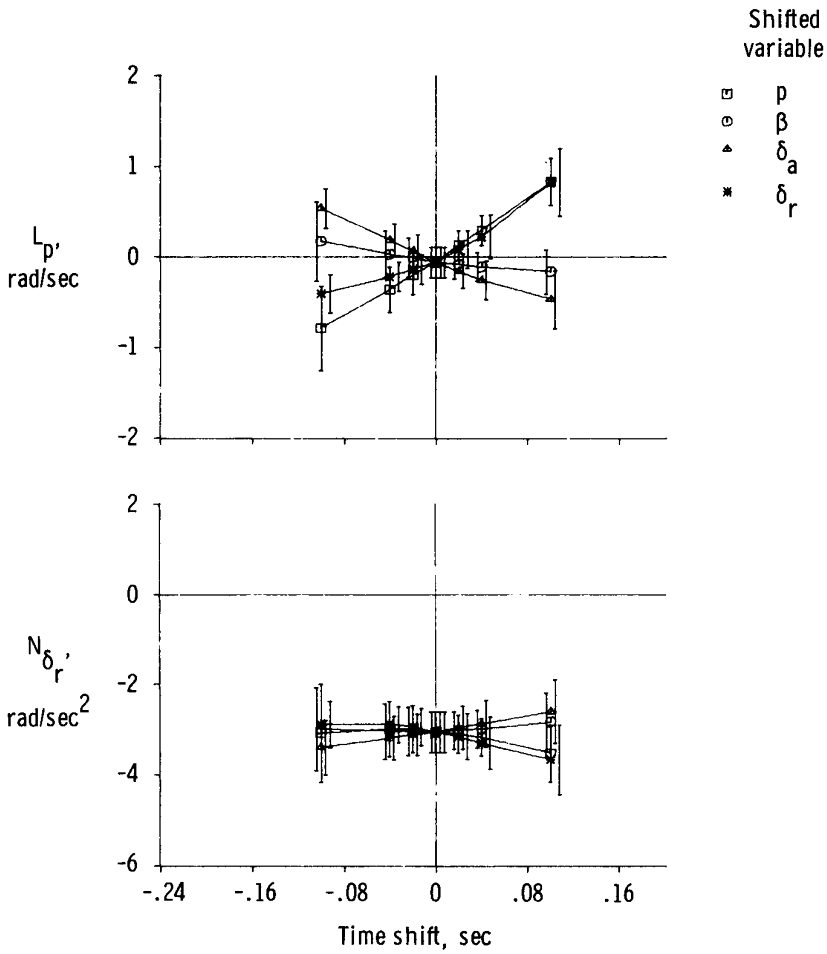
(b)

Figure 12. Continued.



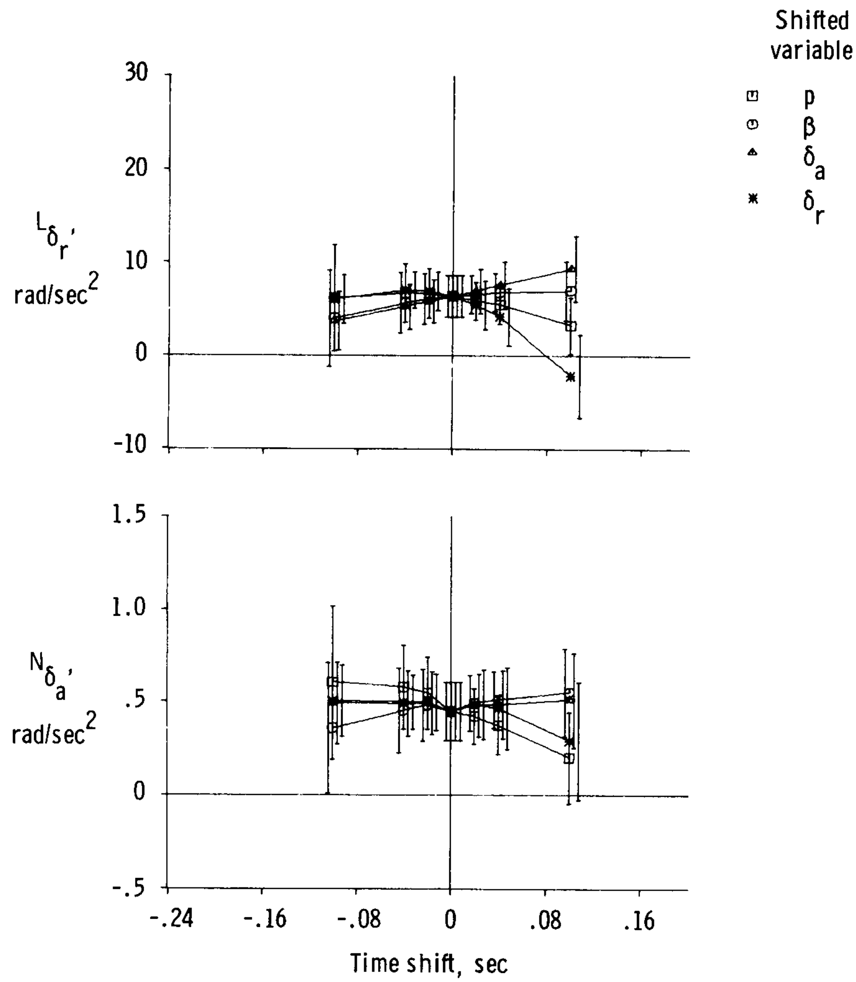
(c)

Figure 12. Continued.



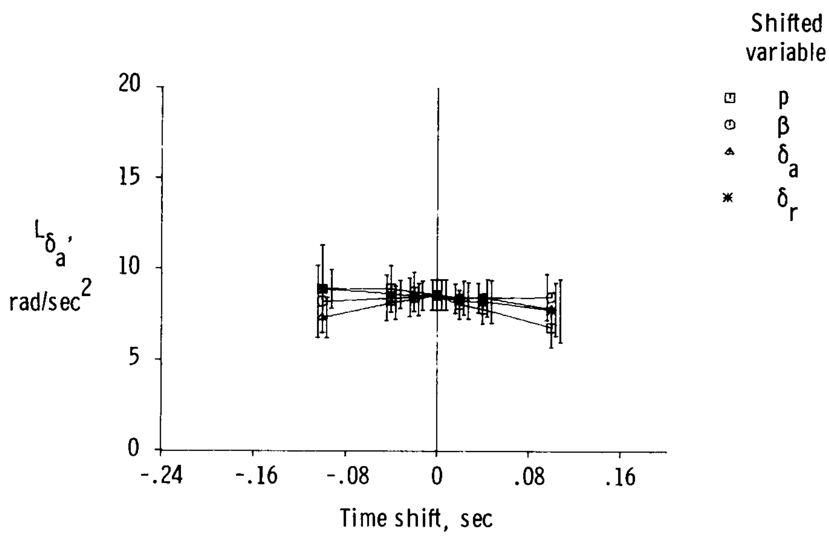
(d)

Figure 12. Continued.



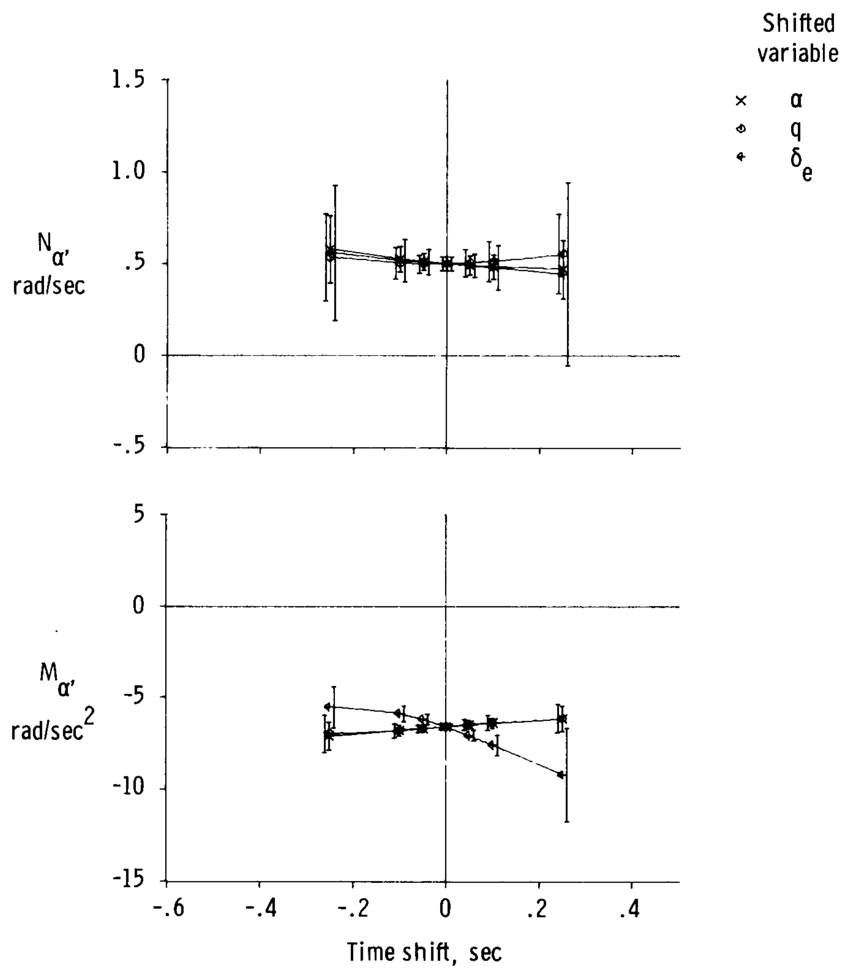
(e)

Figure 12. Continued.



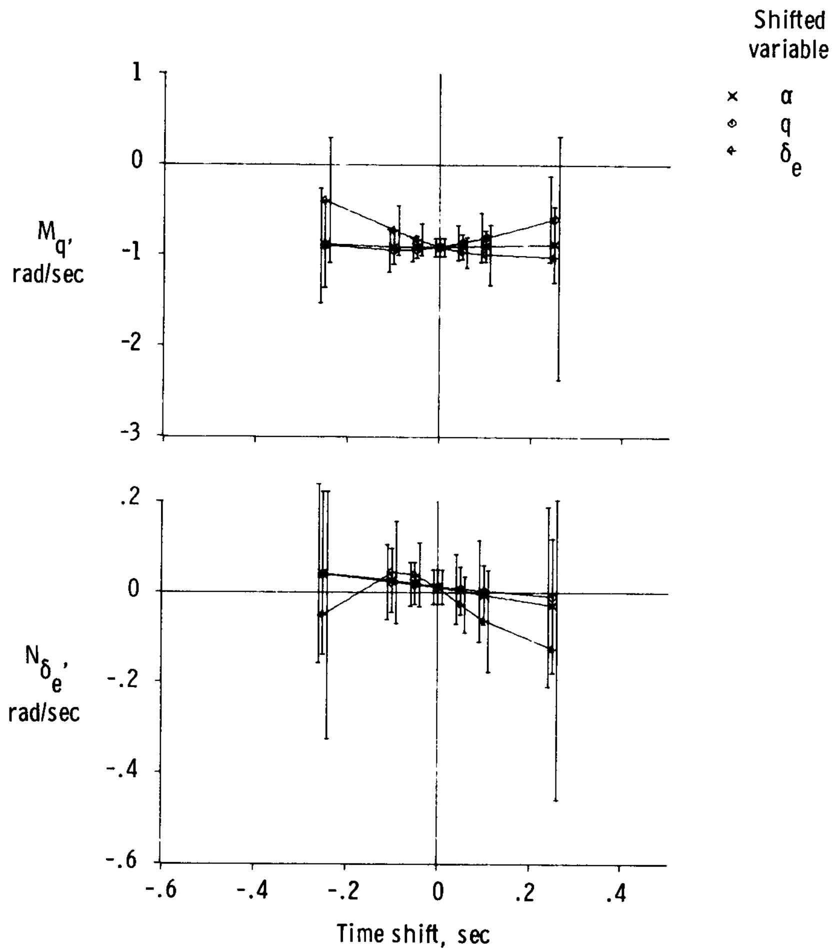
(f)

Figure 12. Concluded.



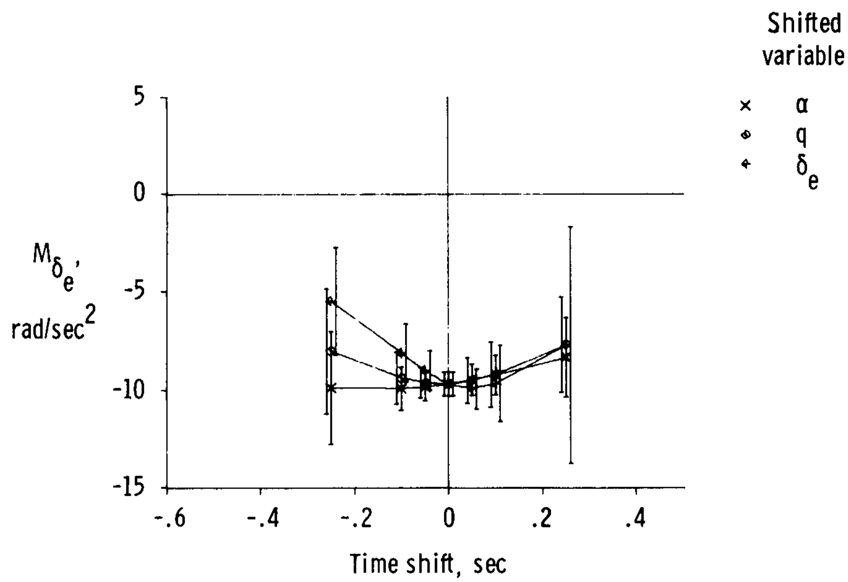
(a)

Figure 13. Estimated longitudinal derivatives and uncertainty levels as a function of time-shift increment for a δ_e maneuver. Aircraft B.



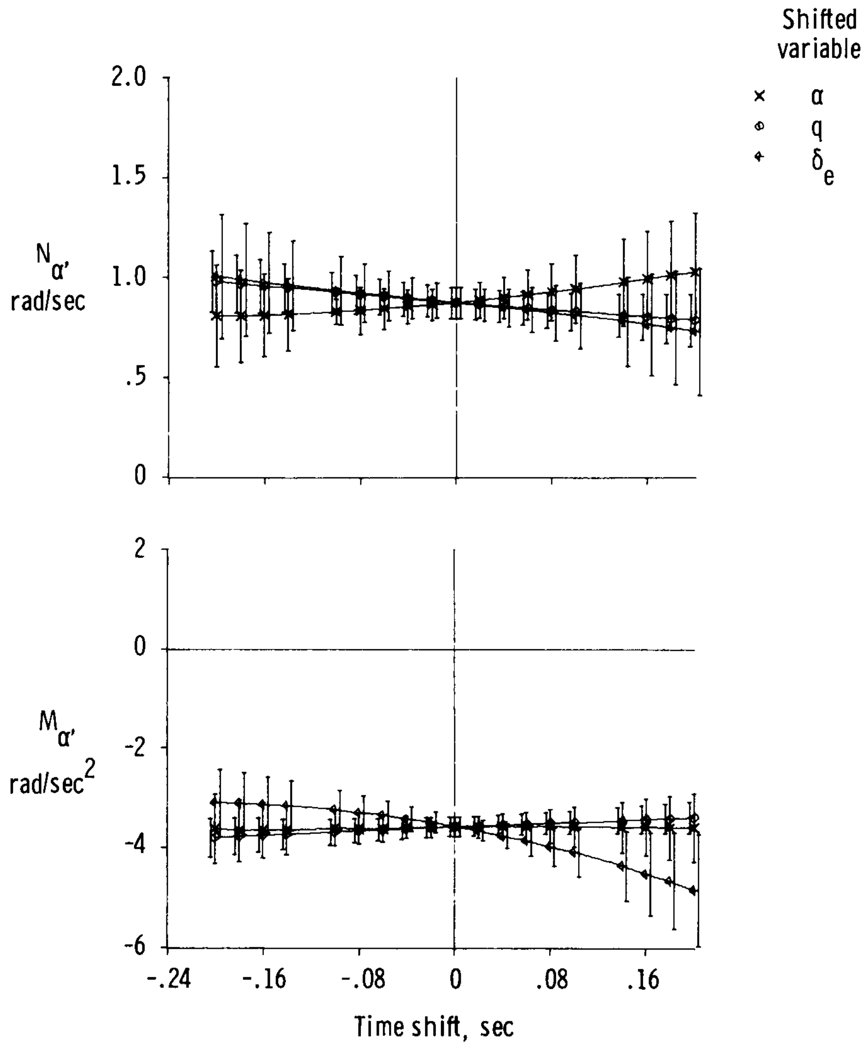
(b)

Figure 13. Continued.



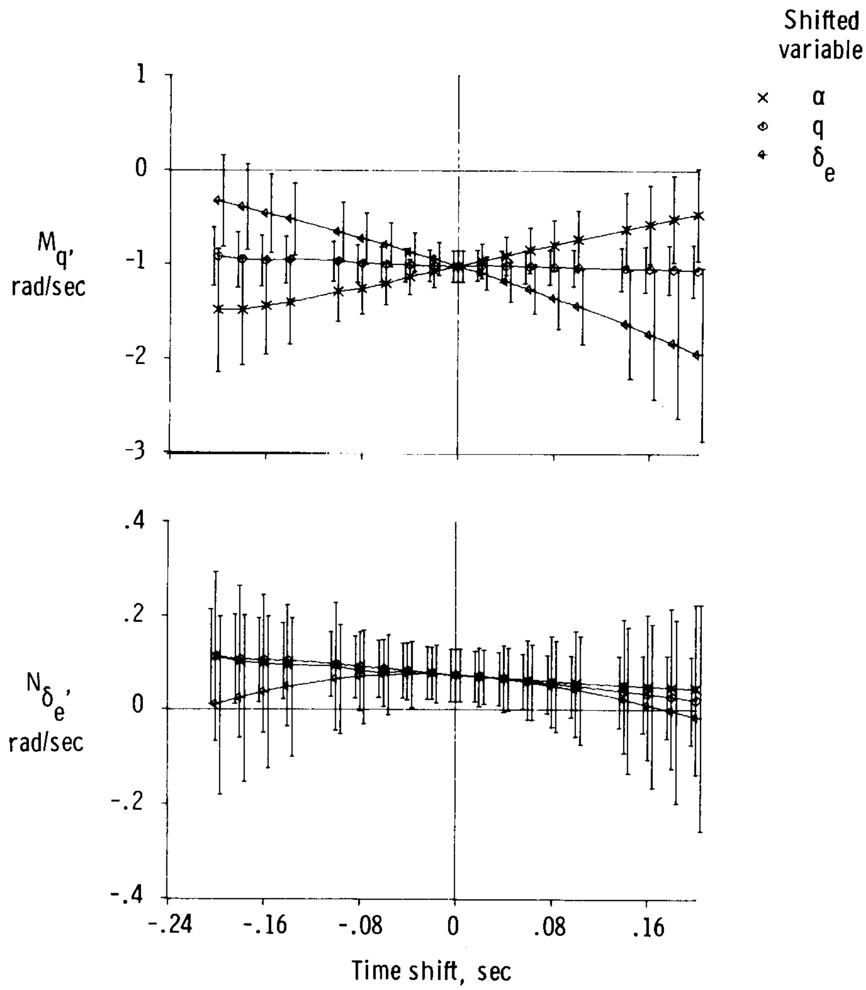
(c)

Figure 13. Concluded.



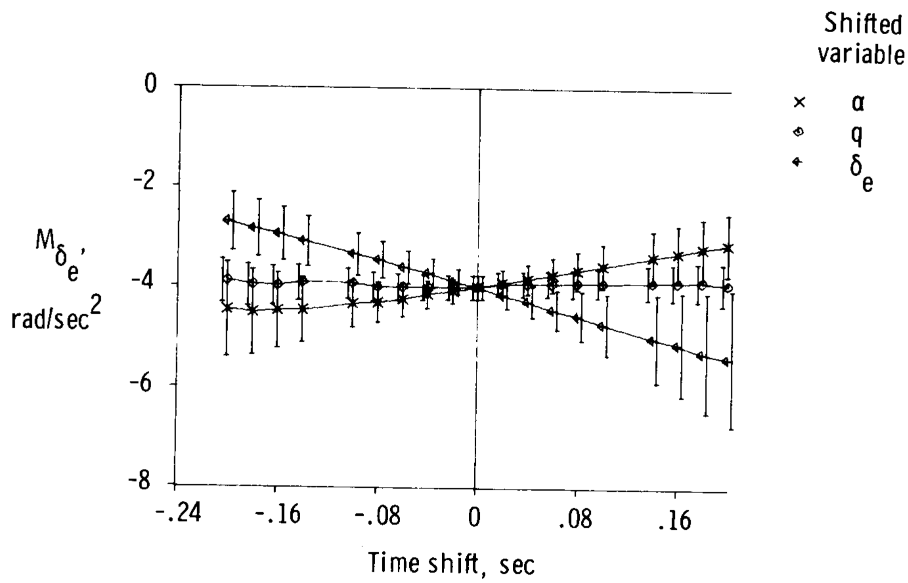
(a)

Figure 14. Estimated longitudinal derivatives and uncertainty levels as a function of time-shift increment for a δ_e maneuver. Aircraft C.



(b)

Figure 14. Continued.



(c)

Figure 14. Concluded.

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